THE UNIVERSITY OF ALBERTA

THE EFFECTS OF FALL BURNING OR GRAZING ON AGROPYRON SPICATUM ((Pursh) Schribn. + Smith) AND ITS SELECTION BY DEER AND CATTLE

by

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Abstract

Studies were made to investigate the effects of fall grazing or fall burning on the physical and chemical properties of *Agropyron spicatum* and on its selection by deer and cattle in spring. The treatment effects were studied in both the *Artemisia tridentata* and *Pseudotsuga menziesii* communities in the south-central interior of British Columbia.

The treatments had little effect on the relationship of plant volume to weight in the first growing season. Although tiller density was greater in burned plants, tiller weight was less. Furthermore, a greater proportion of weight was distributed near the base of burned plants. In the second year the coefficients describing the relationships of volume to weight indicated greater weight in burned plants. This appeared to be related to greater tiller density.

The growth rates of control and fall clipped plants responded similarly to air temperature measured 1.5 m above the ground surface. Plants that were burned in fall grew more rapidly at low air temperature but less rapidly at high air temperature.

Bluebunch wheatgrass tillers were initiated in both communities at about the same time. In the *Pseudotsuga menziesii* community, tiller elongation ceased for a period when the apices appeared above ground surface. This effect appeared related to cooler air temperatures under trees.

Dry matter concentration of minerals (N, P, Ca and Mg) increased and fibrous constituents (ADF, NDF and lignin)

Abstract

Studies were made to investigate the effects of fall grazing or fall burning on the physical and chemical properties of Festuca scabrella and on its use later by deer and cattle in spring. The treatment effects were studied in both the Artemisia tridentata and Pseudotsuga menziesii communities in the south-central interior of British Columbia.

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The growth rates of control and fall clipped plants responded similarly to air temperatures measured 7.5 m above the ground surface. Plants that were burned in fall grew more rapidly at low air temperatures but less rapidly at high air temperatures.

Elongation of reproductive tillers was initiated in both communities at about the same time. In the Pseudotsuga menziesii community, tiller elongation ceased for a period when the spring appeared above ground surface. This effect appeared related to cooler air temperatures under trees.

Dry matter concentration of elements N, P, Ca and Mg increased and tissue constituents (NDF, ADF and lignin)

decreased from the bottom of the plant to the top. This relationship existed for plants of all treatments and, with a few exceptions, in both the first and second year after treatment. The vertical change in the second year was considerably reduced from the first year. The chemical gradient was least for plants of the burned treatment and greatest for untreated plants.

Deer and cattle preferred the burned treatment to the clipped treatment and both were preferred to the control. Deer preferred forage from the burned treatment, to that from the clipped and control treatments, at all levels of utilization. Deer avoided switching to the control by closely utilizing the treated plants. On the other hand, cattle switched to grazing forage from the control when clipped and burned plants were heavily utilized. These preference rakings were generally maintained into the second year. As utilization increased, the weight per bite of forage from the burned and clipped treatments decreased relative to the control. The decrease in bite weight was most dramatic with cattle.

Dead stubble of Agropyron spicatum acted as a barrier to grazing deer and cattle. Burning removed stubble uniformly among plants while grazing left a variable stubble height. Consequently, utilization in spring was more uniform on burned areas than on grazed areas. Deer were more affected by stubble than were cattle although deer were able to select closer to the height of short stubble and further

below the height of long stubble.

Confined deer and cattle selected forage from among treatments in a similar manner to free-ranging animals. Fall grazing influenced the distribution of deer only after spring growth exceeded the height of stubble.

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1. INTRODUCTION

Litter (dead plant material) affects the flow of energy through the ecosystem by storing nutrients, affecting the growing environment of plants and affecting forage selection. Minerals and energy are released from litter upon decomposition. Litter alters the micro-environment in plants by reducing solar radiation and wind speed (Geiger 1966; Knight 1969). Plant growth has been related to litter removal (Tomanek 1969). Litter is unpalatable and avoided by large herbivores.

Available evidence indicates that both forage production and utilization may be increased by removing accumulated litter (Duvall and Whitaker 1964; Barker and Erickson 1974; Rickard et al. 1975; Uresk et al. 1976). Litter may be removed in several ways but more commonly by grazing or burning.

Grazing bluebunch wheatgrass during the growing season generally reduces its' vigor. Sauer (1978) reported a first year decline in production when standing litter was removed during the dormant season. However, increased production may be predicted for over more than one year since higher temperatures increase microbial activity, which may enrich the soil with nutrients, and increase tillering. Burning may increase bluebunch wheatgrass productivity (Uresk et al. 1976) but the effect is influenced by conditions present at the time of fire (Daubenmire 1968). Both burning and grazing encourages greater utilization of regrowth by deer and

cattle (Leckenby 1968; Fierro 1977).

Fire is gaining renewed acceptance as a tool in range management (Duvall and Whitaker 1964; Wright 1974). Perhaps the most noticeable similarity between fall grazing and burning is in litter removal. They contrast in their approach and effect. Fire is most effective in treating areas where litter has accumulated for many years. These areas are avoided by cattle. Burning grasslands enriches the soil with minerals (Daubenmire 1968) but grazing removes or redistributes them. On the other hand, burning releases the energy in forages while harvesting by herbivores converts this to usable products. Burning alters the plant microclimate by removing the canopy and depositing ash. The effect of ash is to increase soil temperature beyond the effect of canopy removal (Geiger 1966). Grazing modifies the microclimate by canopy removal and by undetermined effects on the soil.

Forage selection may be considered the result of four factors: forage availability, consumer selectivity, preference and physiological requirements (Ellis _et al_. 1976). Conditions which lead to selective grazing contribute to reduced efficiency of forage utilization. Bailey (1970) found that the unpalatable shrub, (_Elaeagnus commutata_[1]), acted as a barrier to grazing of understory grasses. In spring, the unpalatable standing dead forage of bluebunch wheatgrass (_Agropyron spicatum_) may act as a barrier to the

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[1]Nomenclature follows Hitchcock and Cronquist, 1973.

herbivore, restricting access to new growth. A more homogeneous distribution of range use should be obtained when palatability differences are removed.

Vegetation provides a medium through which herbivores interact. The interaction is often spaced in time and not obvious. An example is the influence of wildebeest (*Connochaetes taurinus albojubatus*) on the grazing behavior of Thomson's gazelle (*Gazella thomsonii*) on the Serengeti Plains (McNaughton 1976). Both species migrate through the plains but at different times. The wildebeest come first and, by grazing the senescent vegetation, convert the grassland into a productive community with young forage. This forage is sought after by the antelope which follow in about 1 month.

The dry grassland ranges of British Columbia represent an ecosystem comparable to the Serengeti Plains. The herbaceous vegetation is dominated by bluebunch wheatgrass which follows a cyclical pattern of growth represented by late winter initiation and early summer senescence. The mature tillers of bluebunch wheatgrass are erect and persist into the next year. The range is occupied by cattle in fall and late spring, and by mule deer (*Odocoileus hemionus hemionus* in winter and early spring. Cattle grazing in fall removes standing litter of bluebunch wheatgrass and permits the young foliage to be exposed early in spring. Personal observations indicate that only exposed forage is selected by tame and free-ranging deer. There is no direct evidence

that cattle exercise the same degree of selection as deer do.

The decision to remove litter with either fall grazing or fall burning will be based largely on available resources, range conditions and objectives. The first two determine fire effectiveness. The objectives may be to provide forage for one or more classes of herbivores, remove debris or to enhance the competitive ability of a particular species. Whatever the objectives, effects of grazing or burning on forage production and accessibility to the herbivore must be understood. The effects of grazing or burning on bluebunch wheatgrass production have been studied individually (Rickard _et_ _al_. 1975; Uresk _et_ _al_. 1976). Comparative studies on the effects of burning or clipping have been made for grasses of the tall grass prairie (Ehrenreich 1959) but not for bluebunch wheatgrass.

Several studies were made to study the functional interaction between deer and cattle on bluebunch wheatgrass range and to examine the role of fire in the ecosystem. The hypothesis tested was that cattle and deer prefer green grass to standing litter and that litter reduces the production, nutritive value and consumption of green grass. Furthermore, these effects are reduced with increased defoliation.

The objectives of the studies were:

1. To determine the effects of fall grazing or burning on

the plant and it's environment in both the big sagebrush and Douglas fir communities,

a. to determine the effects of fall grazing or burning on the morphological characteristics of bluebunch wheatgrass in spring,

b. to determine the effects of fall grazing or burning on the nutritive characteristics of bluebunch wheatgrass,

c. to determine the growth of bluebunch wheatgrass in relation to fall grazing or burning, to habitat and to time of burning,

d. to determine the effects of fall grazing or burning on soil temperature in spring.

2. To determine the effects of fall grazing or burning on forage selection by cattle and deer in both the big sagebrush and Douglas fir communities,

a. to determine the effect of standing litter (stalk and leaf) on the preference and selection of bluebunch wheatgrass by cattle and deer in spring,

b. to determine the comparative effects of fall grazing or burning on the subsequent availability and palatability of green grass to cattle and deer,

c. to determine how the availability of green grass affects the spring-time distribution of cattle and deer.

1.1 Site Description

1.1.1 Location

The studies were made near Kamloops in south central British Columbia (latitude, 50° 49' N; longitude, 120° 35' W). The studies were made in both the big sagebrush (*Artemisia tridentata*)-bluebunch wheatgrass and Douglas fir (*Pseudotsuga menziesii*)-bluebunch wheatgrass plant communities. Future reference to the communities in the text will be by the first term.

1.1.2 Climate

Kamloops is situated in the interior dry belt with a climate, classified according to Koppen (Trewartha 1954), as BSK middle latitude steppe. Average precipitation at Kamloops, over 65 years, was 26.2 cm with peaks, one in early summer and the other in winter (Fulton 1977). Average daily temperature for that period was 8.3°C. The average daily temperature in both 1976 and 1977 was 8.6°C while the average precipitation for those years was 29.8 and 30.4 cm respectively. Soil water potential at depths of 10 and 50 cm, in Dark Brown Chernozem soils, dropped below -15 bars near the end of May and early June in both years (van Ryswyk and Broersma[2] 1977). This corresponded to the cessation of crested wheatgrass (*Agropyron cristatum*) growth.

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[2]Van Ryswyk, A. and C. Broersma, 1977. Unpublished data.

1.1.3 Soils and Vegetation

The soils and vegetation of the big sagebrush and Douglas fir communities have been described by van Ryswyk *et al*. (1966) and by McLean (1970) for similar areas. Young[3] (1978) has also reported the results of a preliminary soil and vegetation survey of the area. The soils of the big sagebrush community are of the Chernozemic order and Dark Brown great group. The Brown great group may be represented on the south facing slopes of knolls. A variety of soils occur in the Douglas fir community. The most common great group is the Eutric Brunisol of the Brunisolic order. Greater degradation may occur immediately under the canopy of very old trees and no degradation between trees. This leaves the possibility of finding soils from both the Luvisolic and Chernozemic order on that range.

Vegetation zones present at the study area were big sagebrush, ponderosa pine (*Pinus ponderosa*) and Douglas fir. The study sites were situated in the first and last zones. The big sagebrush zone begins at the valley floor situated at 335 meters above sea level (masl), and extends to the open range-tree ecotone at about 600 masl. The ponderosa pine zone is a discontinuous narrow band lying between the other two zones. Its distribution in the southern interior of British Columbia is correlated with the presence of

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[3]Young, G. 1978. Unpublished data. B.C. Ministry of the Environment, Resource Analysis Branch.

coarse soils on glacial till (McLean[4], 1978).

The major plant communities at the study sites were earlier identified as big sagebrush and Douglas fir. A big sagebrush-needleandthread (Stipa comata) community may be interspersed with the former. Their climax composition has been described by McLean (1970) for sites in the Similkameen Valley (Table 1) which is about 150 km south of Kamloops. Saskatoon (Amelanchier alnifolia) was not common in the Douglas fir-bluebunch wheatgrass community of the study area but rabbit bush (Chrysothamnus nauseosus) was. Heavy grazing pressure in the big sagebrush community may result in an increase in the proportion of big sagebrush, Sandberg's bluegrass (Poa sandbergii) and cheatgrass (Bromus tectorum) (McLean 1970).

1.1.4 Geology and Physiography

A description of the geology and physiology of the study area was provided by Fulton (1977). The bedrock is referred to as the "upper Mesozoic Deposits". It consists of volcanic rocks and continental sediments of Cretaceous age unconformably overlaying granitics intrusive bodies. Glaciers, which reached an elevation of 2400 m, had the most marked effect on the physiography. The area was free of ice by 9000 years ago. Volcanic ash was deposited on two occasions since then. The area in the immediate vicinity of the study was characterized by a series of knolls about 300

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[4]McLean, A. 1978. Personal communication.

Table 1. Climax composition of species, that attain a constancy of over 80%, for communities present on the study area (Table adapted from McLean, 1970).

Species	Artemisia-Agropyron	Artemisia-Stipa	Pseudotsuga-Agropyron
	Community — Coverage (%)		
Grasses			
Agropyron spicatum	44a	-	7-68c
Bromus tectorum	T	T-3b	-
Festuca octoflora	T	-	-
Koeleria cristata	-	-	0-7
Poa sandbergii	1	17-34	-
Stipa comata	-	27-68	-
Forbs			
Arabis holboellii	-	-	0-1
Balsamhoriza sagittata	-	-	0-2
Crepis atrabarba	3	-	0-1
Lappula redowski	-	-	-
Lomatium macrocarpum	3	T-1	-
Microsteris gracilis	7	-	-
Selaginella wallacei	-	-	0-69
Shrubs			
Amelanchier alnifolia	-	-	0-1
Artemisia tridentata	7	7-22	-

T Less than 1%.
a Mean values from two sites.
b Range of values from three sites.
c Range of values from nine sites.

m above Kamloops Lake (335 masl). An alluvial fan forms a flat field between the knolls and open range-tree ecotone. Bedrock occurs at or near the surface on the knolls.

1.1.5 Regional Significance of the Study Area

The rangeland of British Columbia comprises about 9 million (M) hectares (ha) of the 106 M ha total provincial area. Of the rangeland, about 1.4 M ha consists of open grassland which may be partitioned into areas of Sagebrush, Middle Grasslands, Fescue Grasslands, Alpine Grasslands and Sedge Meadows in ratios of 1:1:3:2:1 respectively. The Sagebrush area is basically the big sagebrush-bluebunch wheatgrass community described earlier. No estimates of area were found for the Douglas fir-bluebunch wheatgrass community. However, within the study area both communities appeared equally represented.

The big sagebrush and Douglas fir communities in the Kamloops area are normally utilized by cattle for 2 to 4 weeks in spring and for a similar length of time in fall. The stocking rate recommended for good range is about 1.5 ha per animal unit month (McLean and Marchand 1968). Deer may utilize the same range from December to May. Their migration appears to be in response to vertical gradients of weather and forage although hunting pressure in the fall ensures late migration onto the lower range. Deep snow at high elevations and the early flush of grass at lower elevations stimulate a downward migration in winter and spring while

early maturing forage and hot weather in late spring prompt a return to higher altitudes. Annual and seasonal use of the range by deer is thus highly variable and its importance relative to other ranges cannot be compared simply on the basis of area.

2. APPROACH

The studies fall into two parts. One part examines the effects of fall grazing or fall burning on the plant while the other part examines effects of these treatments on the plant-animal interactions. The two parts are related through the interaction.

Treatments were applied in the fall of 1975 and 1976 and data obtained in April and May of 1976 and 1977. The plant data reported in part I was all collected in 1977 from both treatment years. Data collections within any month were made in two communities; first in the big sagebrush community and then in the Douglas fir community. The collection interval between treatment years was 5 to 7 days and between communities for the same treatment year, 10 to 14 days.

The studies on plant morphology, plant chemistry and forage selection used plant material common to each. Basically, the plant material used to examine the first and second year treatment effects on plant morphology was also used to analyse the first and second year treatment effects on plant chemistry. It also provided the necessary data to define the relationships of volume to weight and height to weight used to estimate availability and utilization of bluebunch wheatgrass in the 1977 trials. Therefore, the sampling dates and locations coincided with those of the animal trials.

Studies on the animal may be categorized according to 1 of 3 levels of experimental constraint imposed on them. The constraints imposed were on the size of study area, the relative proportion of area in each treatment and the method of litter removal. The first and second levels confined tame animals to enclosures. The enclosures in the first level were 1/7th the area of the second. The proportion of area among treatments in the first level was the same while in the second level it was unbalanced. Furthermore, in the first level fall grazing was simulated by mechanical removal while in the second level fall grazing was imposed by cattle. In the third level the observations were on free ranging animals and the proportion of treated area was very small relative to the control.

The treatment effect at the first level of study was examined the first and second year after treatment. The nature of the information lends itself to discussion in two chapters. One chapter pertains to the first level of constraint dealing primarily with forage preference and foraging strategy. The other chapter deals with forage selection and distribution of use, studied at both the second and third levels of constraint. Observations from all studies were made in both the big sagebrush and Douglas fir communities and at increasing levels of utilization.

The procedure for estimating available and utilized forage in the selection trials differed between years. In the first year (1976), only plants of the control were used

to define the relationships of volume to weight and height to weight for all treatments while in the second year (1977), plants from individual treatments were used to define those relationships. Furthermore, in the first year the regression equations describing those relationships were forced near the X,Y coordinates of 0,0 (and 1,1 for the relationship of height to weight described as a proportion of the total) by entering those values with each data set. In the second year, however, the regression equations were forced through those coordinates by statistical methods (Greig and Bjerring 1977).

Part 1

TREATMENT EFFECTS ON THE PLANT

3. PLANT MORPHOLOGY AND GROWTH

3.1 Methods

The methods may be categorized into three studies according to their objectives. The first study deals with the comparative aspects (physical properties) of fall clipping or fall burning on the plant. The second study compares the growth of bluebunch wheatgrass between areas burned in the fall and spring and the third examines initiation of spring growth in bluebunch wheatgrass, crested wheatgrass and Sandberg's bluegrass. All observations were made in the spring of 1977.

3.1.1 Effects of Fall Clipping or Burning on Plant Morphology and Growth

3.1.1.1 First Spring after Treatment

The design of the study was a 3x3 Latin square repeated in both the big sagebrush and Douglas fir communities. Each plot was 20^2m. The fall treatments were clipping, burning and no disturbance (control). The plots were burned with the aid of a propane torch in November, 1976, when the relative humidity was about 60% and the temperature 3°C. Clipping was done with an electric powered sickle bar. Electricity was obtained from a portable, gasoline powered generator. The average stubble heights of the clipped and burned plants were about 5 and 1.5 cm respectively.

Plant Morphology

Twenty or more bluebunch wheatgrass plants were sampled from each treatment in both April and May in each community. Selection was from 1-m^2 sub-plots placed systematically in rows, beginning 0.5 m from the lower end of the plot. A single row of sub-plots was sampled at each date. Twelve sub-plots from each treatment were thus available from which plants were selected. Plants were eliminated from selection if their basal circumference was non-uniform or if their circumference was already represented in the sample. The circumference of the plants selected ranged from 4 to 55 cm. Plant height was measured from the ground to the average length of the three longest tillers measured to the tips of vertically extended leaves. If one or two long leaves extended considerably above the average for the plant, they were ignored and the next longest ones were measured. After measurement, the plants were clipped at 1.5 cm, individually bagged and frozen. Final sample preparations were made by separating the green foliage from standng litter, counting the tillers of the former and dissecting into five parts of equal length. Dissectioning was done by aligning the basal ends of the tillers and cutting the plant, from the base, into lengths defined by the measured height of the plant, less 1.5 cm, and divided by 5. The individual parts were bagged, dried at 65°C and weighed. The total green weight of each plant was the sum of its five parts. The forage material was retained for later chemical analysis.

Dry matter density and dry matter distribution within the plant were determined from relationships of plant volume to weight and plant height to weight respectively. Plant volume (cc) was calculated as a cylinder. Polynomial regressions were calculated to describe the relationships of plant volume(X) to weight(Y) and of height(X) to weight(Y). For the latter regressions the dependent variable was the proportion of accumulated weight from the base while the independent variable was the proportion of accumulated height from the base. The regressions of both relationships were forced through the 0, 0 coordinates while the regressions of height to weight were also forced through the 1, 1 coordinate. Dry matter density and dry matter distribution were, therefore, defined by the regression coefficients of their respective equations. The regression of each relationship was tested for significance ($P<0.05$) to the 3rd degree.

The analysis of variances model partitioned variation among 3 treatments, between 2 communities and between 2 months. The covariates were X, X^2 and X^3 (X=proportion accumulated weight) and were crossed with the main factors. Variation consisted of individual plant weights for the model of volume to weight and the proportion weight per segment for the model of height to weight. The variation contributed by a term (covariate, or a covariate-main factor(s) interaction) was determined by the difference in variation between the full model and the sub-model with the

term deleted. Residual variation was calculated as the difference accounted for by the full model and the total variation in the data.

The minimum of the Bonferroni and Scheffe' ranges were used to test for significant differences ($P<0.05$) between coefficients. This test is conservative and has been suggested as appropriate when testing among regression coefficients (Greig and Bjerring 1977).

Number of tillers per plant were compared among treatments and trials using analysis of covariance with area (cm^2) and $\sqrt{area}$ as covariates. The first variate adjusted the estimate for plant size and the second adjusted for edge effect. The Duncan's multiple range test was used to test for significant differences ($P<0.05$) among means. The treatment effect on tiller weight was analysed using analyses of variance and the Duncan's multiple range test.

Effect of Soil and Air Temperature on Plant Growth

Single 1-m^2 sub-plots were established in each plot in areas with high plant density and little interference from shrubs. Corners of sub-plot were marked with steel pins and the bluebunch wheatgrass plants mapped on a grid. Initial measurements, made on 21 March, consisted of the basal circumference and height of green foliage. Plant heights were measured weekly, as described above, until 19 May in the big sagebrush community and until 3 May in the Douglas

fir community. Observations in the latter community were terminated early as a result of disturbances from free-ranging deer.

Soil and air temperatures were measured concurrent with growth. One Stevenson screen, with a monthly recording thermograph, was established at each site. Soil temperatures were measured at four depths at discrete weekly intervals in each plot, thus providing three measurements per treatment at each depth. Temperatures were recorded at 0, 2.5, 10 and 20 cm in the centers of individual plants. Plants selected for measurement were unprotected by shrubs and had a basal area of at least 40^2 cm. Consecutive weekly measurements on the same plant were avoided. Temperatures were recorded between 1 and 3 p.m. The top two measurements were made using thermister probes and the bottom two measurements were made using dial thermometers with a bimetallic element. The thermometers were tested for accuracy prior to the trials and the readings adjusted accordingly. Analysis of variance, with Duncan's multiple range test, was used to test for weekly treatment effect.

The daily maximum and minimum air temperatures were averaged for the interval between plant measurements. The average daily maximum soil temperature, at 2.5 cm, for the same period was estimated as the average of two measurements taken at the beginning and end of the period.

The relationship of growth rate (Y=cm /day) on temperature (X=°C) were tested for significance to the third

degree polynomial according to Goulden (1952). The temperature variables examined in separate analyses were maximum and minimum air temperatures, average daily air temperature and average daily maximum soil temperature at 2.5 cm. The regression coefficients among treatments were tested for similarity using the t-test (LeClerg et al. 1962).

The difference between two treatment effects on weekly growth rates was analysed using the unpaired t-test (LeClerg et al. 1962). The effect of plant basal area on growth was examined with regression techniques described above for temperature (Goulden 1952).

3.1.1.2 Second Spring after Treatment

Plant material was obtained in the second spring after treatment (1977), within areas of the preference trials described in chapter 5. Three collections were made prior to grazing: two from the big sagebrush community (one in April and another in May) and one from the Douglas fir community in May. The collections in April consisted of 10 plants per treatment while the collections in May consisted of 19 to 21 plants per treatment. The criteria for plant selection, the collection procedure, and the post-collection treatment were the same as described earlier but with one exception pertaining to the mature forage. This material was sorted into age classes of one and more than one year old material and the latter category was discarded. The one year old

material (1976 post-grazing regrowth) was then prepared in a similar manner as the current growth, but was not segmented for calculation of the weight-height relationships.

3.1.2 Seasonal Effect of Burning on Growth

Two areas were burned in similar habitats in the big sagebrush community. One was burned in November (1976) and the other in March (1977). The percent relative humidity and temperatures were, respectively, 62% and 5°C in November and 37% and 13°C in March. Burning was assisted with a propane torch. In the first burn each plant was ignited individually while in the second the fire spread with little assistance. The pre-treatment heights of fifty plants, selected randomly, were measured at each site to compare potential site differences. On 20 April fifty treated plants were selected randomly and their heights measured. An unpaired t-test (LeClerg *et al.* 1962) was used to examine differences between the average plant heights from each site.

3.1.3 Initiation of Spring Growth

Appearance of spring growth was observed in bluebunch wheatgrass, Sandberg's bluegrass and crested wheatgrass by extracting the crowns of five plants of each species and examining them for tiller initiation and elongation. The lengths of the first five spring-initiated tillers found in each crown were measured. Observations began on 10 February and were made weekly. Bluebunch wheatgrass and Sandberg's

bluegrass plants were examined in both the big sagebrush and Douglas fir communities but crested wheatgrass plants only in the former.

3.2 Results

3.2.1 Effects of Fall Clipping or Burning on Plant Morphology and Growth

The models used to test the regression coefficients of equations describing the relationships of both volume to weight and height to weight accounted for 92 and 99.8% respectively of the total variation within the data. Part correlation coefficients for the covariates and their interactions with the main factors were not calculated. The polynomial equations describing the relationships of volume to weight were significant ($P<0.05$) only at the first degree while the equations describing the relationship of height to weight were significant at the 3rd degree. From 66 to 71% of variation present in the model testing tiller density was accounted for by the main factors and covariates. However, the factors in the model testing tiller weight accounted for only 26% of total variation.

3.2.1.1 Plant Morphology

First Spring after Treatment

Dry matter density within bluebunch wheatgrass plants did not differ significantly either among treatments or between communities. This is indicated by lack of

significant differences ($P>0.05$) among regression coefficients describing the relationship of volume to weight (Table 2).

The relationships of height to weight indicate a more rapid accumulation of dry matter near the base of burned plants than in control plants (Table 2). In general, the first and third coefficients were smallest in the control and largest in the burn treatment while the second was largest in the control and smallest in the burn treatment. An example of an equation, reconstructed from table 2 (for the control in the big sagebrush community in April), was: $Y=2.512X - 1.870X^2 + .353X^3$. The first regression coefficient (b1) differed significantly ($P<0.05$) both among treatments and among trials (Table 2). However, the second (b2) and third (b3) coefficients differed significantly only among trials.

Tiller density was greater in burned plants than in clipped or control plants (Table 3). Tiller densities in all treatments were also greatest in the big sagebrush community. There was also a consistent trend for tiller weights to be lower in burned plants than in clipped or control plants (Table 4). Trial averages reveal that in May, tillers were less dense but heavier in the Douglas fir community than in the big sagebrush community.

Second Spring after Treatment

Table 2. Regression coefficients describing the relationships of (1) green volume (X=cc) and green weight (Y=gm) and (2) green height (X= proportion from base) and green weight (Y=proportion from base), for plants in the first growing season after fall treatment (n=90 to 140).

Treatment	*Artemisia tridentata* April	*Artemisia tridentata* May	*Pseudotsuga menziesii* April	*Pseudotsuga menziesii* May
		Volume-Weight†		
Control	.00197±.00028	.00207±.00010	.00110±.00029	.00166±.00010
Clip	.00107±.00037	.00228±.00012	.00098±.00017	.00143±.00010
Burn	.00140±.00033	.00206±.00014	.00070±.00033	.00170±.00013
		Height-Weight b1		
Control	2.512cdef±.055	1.898a ±.052	2.232bc ±.056	1.881a ±.058
Clip	2.723ef ±.061	2.234b ±.053	2.396bcde±.061	2.106ab ±.059
Burn	2.787f ±.050	2.228b ±.048	2.548def ±.053	2.314bcd ±.059
		b2		
Control	-1.870abc ±.160	- .664de ±.150	-1.243cde ±.164	- .490e ±.168
Clip	-2.331ab ±.178	-1.305cde ±.153	-1.581bcd ±.178	- .963de ±.168
Burn	-2.486a ±.144	-1.376cd ±.138	-1.954abc ±.153	-1.342cde ±.173
		b3		
Control	.353abcd±.110	- .233a ±.103	.00634abc±.113	- .395a ±.116
Clip	.604cd ±.122	.0670abc±.105	.185abcd ±.122	- .148ab ±.116
Burn	.696d ±.0990	.144abc ±.0954	.402bcd ±.105	.0216abc±.119

† Regression coefficients (±1 SEm) of linear equations do not differ significantly (P > 0.05) among treatments.

b_1, b_2, b_3 Partial regression coefficients (±1 SEm) of cubic polynomial equations.

a–f Regression coefficients with the same letter, within row and column of subset, do not differ significantly (P > 0.05).

Table 3. Tiller densities in two communities the first growing season after fall treatment.

Treatment	Artemisia tridentata April	Artemisia tridentata May	Pseudotsuga menziesii April	Pseudotsuga menziesii May	Treatment mean	n
Control	78.2bc+	66.9b	56.6ab	54.5ab	64.6d	91
Clip	76.5bc	75.7bc	63.7b	31.1a	60.9d	84
Burn	99.5c	76.5bc	52.0ab	79.4bc	77.4e	100
Trial mean	86.3g	73.2g	56.9f	53.4f		
n	70	76	67	62		

+ Number tillers per plant adjusted by covariates: area and $\sqrt{area}$.

a-c Means with same letter in row and column do not differ signficantly (P > 0.05).

d&e Treatment means with same letter in column do not differ significantly (P > 0.05).

f&g Trial means with same letter in row do not differ significantly (P > 0.05).

Table 4. Tiller weights in two communities the first growing season after fall treatment.

Treatment	Artemisia tridentata April	Artemisia tridentata May	Pseudotsuga menziesii April	Pseudotsuga menziesii May	Treatment mean	n
Control	.020ab±.014+	.066bc ±.014	.024abc±.014	.085c ±.016	.047e	91
Clip	.014ab±.016	.051abc±.014	.025abc±.016	.186d ±.014	.074e	84
Burn	.014ab±.013	.043abc±.013	.012a ±.014	.056abc±.016	.024e	100
Trial mean	.016f	.053g	.020f	.104h		
n	70	76	67	62		

+ Tiller weight (gm/tiller) ± 1 SEm.

a-d Means with same letter in row and column do not differ significantly ($P > 0.05$).

e Treatment means do not differ significantly ($P > 0.05$).

f-h Trial means with same letter in row do not differ significantly ($P > 0.05$).

The post-grazing regrowth in the first spring was measured as weathered forage during the second spring. The regression coefficients indicate that dry matter density was significantly greater ($P<0.05$) in burned plants in the big sagebrush community (Table 5). However, in the Douglas fir community, dry matter density was smallest in burned plants. Community differences for the control and clipped treatments were not significant ($P>0.05$).

In the second year after treatment, regression coefficients describing the relationship of volume to weight indicate that dry matter density increased from the control to the clipped to the burned treatments (Table 6). However, differences were significant ($P<0.05$) only between the control and burn treatments in May in the big sagebrush community. Differences also occurred among trials (Table 6). In the big sagebrush community, those coefficients representative of data for May were larger than those for April. In May, regression coefficients from treated plants in the big sagebrush community were larger than those in the Douglas fir community.

The dry matter distribution within plants was similar among treatments. This is shown by the regression coefficients of polynomial equations describing the relationship of height to weight (Table 6). However, differences among trials were evident. A greater proportion of dry matter was distributed near the base of plants in April than in May.

Table 5. Regression coefficients describing the relationship of volume (X=cc) and weight (Y=gm) for weathered forage produced post-grazing the first growing season after fall treatment.

Treatment		Artemisia tridentata	Pseudotsuga menziesii	Treatment mean	n
Control		.00295bc ±.00031	.00348c ±.00027	.00334f±.00020	39
Clip		.00293abc±.00039	.00170ab±.00033	.00233e±.00025	40
Burn		.00517d ±.00033	.00146a ±.00030	.00321f±.00022	41
Community	mean	.00364h ±.00020	.00228g ±.00017		
n		60	60		

a-d Regression coefficients (±1 SEm) with same letter in row and column do not differ significantly ($P < 0.05$).

e&f Treatment means with same letter in column do not differ significantly ($P > 0.05$).

g&h Community means with same letter in row do not differ significantly ($P > 0.05$).

Table 6. Regression coefficients describing the relationships of (1) green volume (X=cc) and green weight (Y=gm) and (2) green height (X=proportion from base) and green weight (Y=proportion from base) for plants in the second growing season after fall treatment.

Treatment	*Artemisia tridentata* Species-Month+ Deer-April	*Artemisia tridentata* Species-Month+ Cattle-May	*Pseudotsuga menziesii* Species-Month Cattle-May
		Volume-Weight (n=10-20)	
Control	.00082a ±.00020	.00280bc±.00013	.00193abc±.00011
Clip	.00131ab ±.00043	.00325c ±.00016	.00197ab ±.00013
Burn	.00208abc±.00044	.00496d ±.00013	.00228b ±.0012
		Height-Weight (n=50-100)	
		b1	
Control	2.376bc ±.0798	2.040ab ±.0595	1.777a ±.0579
Clip	2.491c ±.0798	1.963a ±.0579	1.854a ±.0579
Burn	2.448c ±.0798	2.035ab ±.0564	1.855a ±.0595
		b2	
Control	-1.625abc±.232	-1.081abcd±.173	-.512d ±.168
Clip	-1.841a ±.232	- .948abcd±.168	-.616cd ±.168
Burn	-1.805ab ±.232	- .981abcd±.164	-.705bcd±.173
		b3	
Control	.246a ±.160	.0388a ±.119	-.269a ±.116
Clip	.347a ±.160	.0175a ±.116	-.243a ±.116
Burn	.355a ±.160	-.0568a ±.113	-.154a ±.119

\+ Grazing animal and month of grazing in the first growing season after treatment.

a-d Regression coefficient (±1 SEm) with the same letter, within row and column of subset, do not differ significantly ($P > 0.05$).

b_1, b_2, b_3 Partial regression coefficients (±1 SEm) of cubic polynomial equations.

Tiller density in the second spring remained similar or increased from tiller density in the first spring (Table 7). In both seasons tiller density was highest among the burned plants and decreased from the clipped to the control treatments. Tiller density was significantly ($P<0.05$) less in the Douglas fir community than in the big sagebrush community.

There were no significant differences in tiller weights among treatments (Table 8). However, there was a consistent trend for tillers to be heavier in control plants. In trial averages, tillers in the Douglas fir community were heavier than in the big sagebrush community.

3.2.1.2 Growth - First Spring after Treatment

Average weekly maximum and minimum air temperatures are shown, for both the big sagebrush and Douglas fir communities, in figure 1. Temperatures in the big sagebrush community were consistently greater than those in the Douglas fir community. Soil temperatures at all depths (Fig. 2) followed the pattern established by the maximum air temperature. Temperatures were higher in the soils of the big sagebrush community than of the Douglas fir community until April. At this time they become similar. Temperature differences at the 0 and 2.5 cm depth, were calculated for each treatment (Table 9). The average differences from the contol plants, in the big sagebrush community, were, at the 0 cm depth, +1.89 and +2.14°C respectively and, at the 2.5

Table 7. Tiller densities, following grazing in the first growing season, in two communities and in two growing seasons after fall treatment.

Treatment	Artemisia tridentata Species-Month[+] Deer-April	Artemisia tridentata Species-Month[+] Cattle-May	Pseudotsuga menziesii Species-Month Cattle-May	Treatment mean	n
		Post-grazing in first spring after treatment			
Control	76.9bc[†]	53.3ab	27.2a	47.4f	49
Clip	107.2cd	71.3bc	60.9b	74.3f	50
Burn	147.8d	134.4d	70.5b	112.0g	51
Trial mean	110.6j	87.7i	52.9h		
n	30	60	60		
		Second spring after treatment			
Control	91.9bc	90.4bc	53.2a	75.5f	49
Clip	105.9bcd	113.6cd	69.0ab	94.2f	50
Burn	140.5de	165.0e	76.8ab	125.6g	51
Trial mean	112.8i	124.2i	66.3h		
n	30	60	60		

+ Grazing animal and month of grazing in the first growing season after treatment.

† No. tillers per plant adjusted by covariates: area and $\sqrt{\text{area}}$.

a-e Means with same letter in row and column of subset do not differ significantly ($P > 0.05$).

f&g Treatment means with same letter in column of subset do not differ significantly ($P > 0.05$).

h&j Trial means with same letter in row of subset do not differ significantly ($P > 0.05$).

Table 8. Tiller weights in two communities the second growing season after fall treatment.

Treatment	*Artemisia tridentata* Species-Month[+] Deer-April	*Artemisia tridentata* Species-Month[+] Cattle-May	*Pseudotsuga menziesii* Species-Month Cattle-May	Treatment mean	n
Control	.025a±.022[†]	.065a±.016	.089a±.016	.066b	49
Clip	.021a±.022	.058a±.016	.074a±.016	.057b	50
Burn	.022a±.022	.059a±.015	.074a±.016	.058b	51
Trial mean	.022c	.060d	.079e		
n	30	60	60		

+ Grazing animal and month of grazing in the first growing season after treatment.

† Tiller weight (gm/tiller) ± 1SEm.

a Means with same letter in row and column of subset do not differ significantly (P > 0.05).

b Treatment means with same letter in column of subset do not differ significantly (P > 0.05).

c-e Trial means with same letter in column of subset do not differ significantly (P > 0.05).

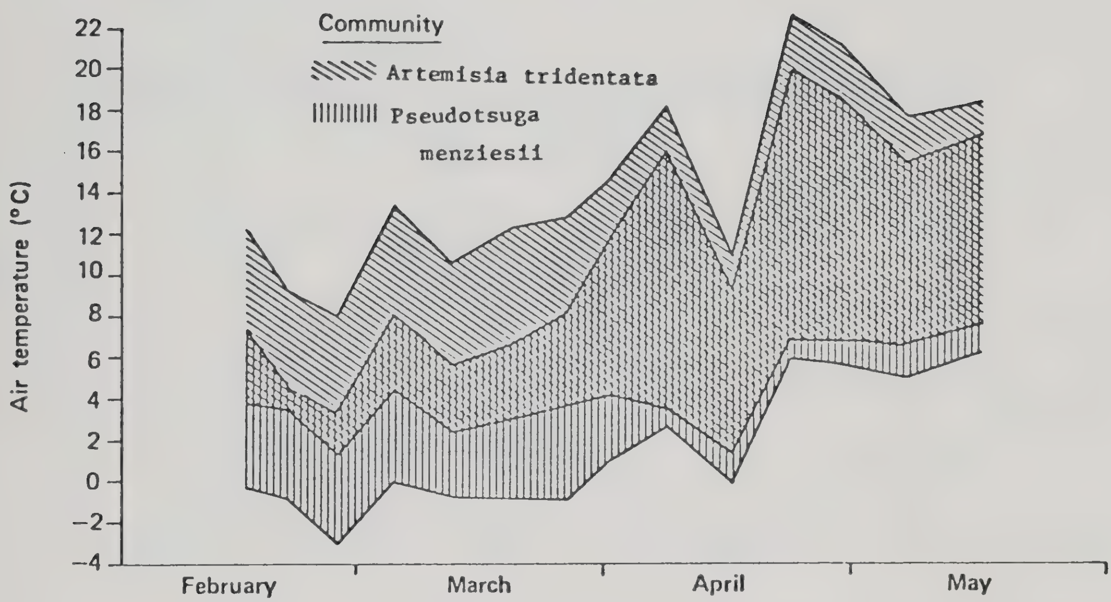

Figure 1. Weekly average maximum and minimum air temperatures from February to May, 1977, in two communities.

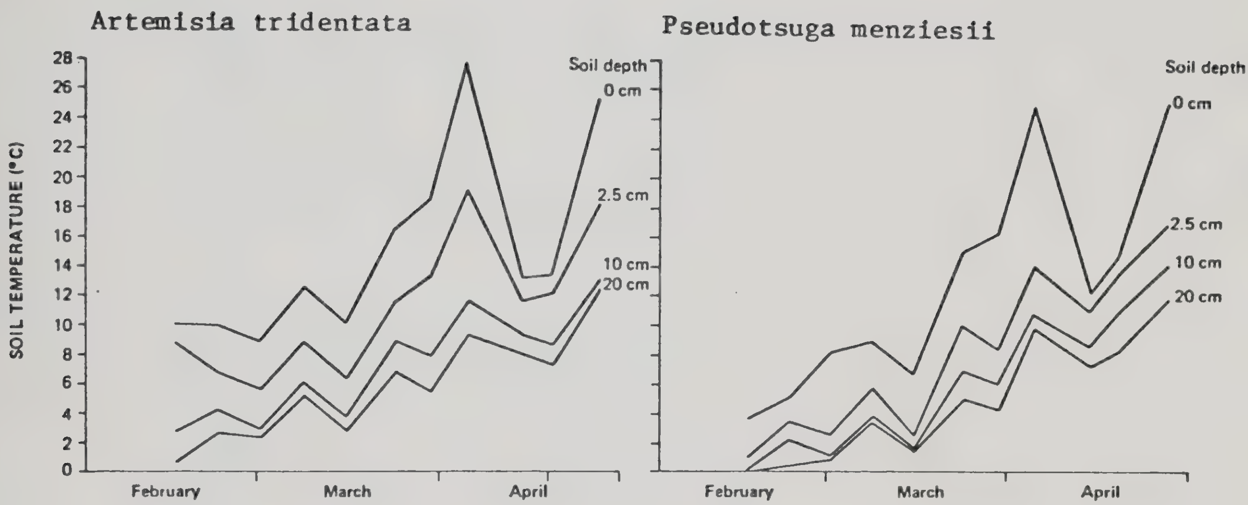

Figure 2. Weekly soil temperatures at four depths from February to April in two communities (averaged for all treatments).

Table 9. Weekly within-plant soil temperatures (± 1 SEm) among treatments at 0 and 2.5 cm soil depths, from February to April, 1977, in two communities (n=3).

		Artemisia tridentata						Pseudotsuga menziesii					
		Soil depth						Soil depth					
		0 cm			2.5 cm			0 cm			2.5 cm		
Date	Weather	Control	Clip	Burn	Control	Clip	Burn	Control	Clip	Burn	Control	Clip	Burn
Feb 15	Sunny, mild	10.1± .5	9.5±1.0	10.7± .2	9.5±1.7	7.9±1.1	8.7± .8	3.1±1.5	3.8± .7	3.9± .6	.7± .7	.3± .1	1.6±1.5
22	Sunny, mild	8.8± .4a	10.1± .2b	10.8± .4b	6.0± .9	7.0± .7	7.1± .1	3.7±1.0	5.7± .8	5.8± .6	2.5± .8	3.7± .8	4.1± .2
Mar 1	Sunny, mild	7.4±1.0	9.5± .5	9.4± .7	4.5± .1	5.5± .5a	6.7± .8ab	4.8±1.5b	10.0±1.3	9.3±1.3	1.1±1.0	2.0±1.4	4.5±2.8
8	Cloudy, mild	11.6± .5	12.2± .4	13.4± .6	8.2± .5	8.3± .9	10.0± .4	8.1±1.1	8.9± .6	9.0± .2	4.8± .8	6.2± .2	6.2± .5
15	Cloudy, mild	8.3± .8a	10.3± .6ab	11.3± .6b	6.2± .6	5.3± .4	7.4± .9	6.1± .8	6.6±1.7	7.2± .9	1.7± .6ab	1.4± .6a	2.7± .5b
23	Sunny, wind	16.0±1.0	17.5±1.2	16.0±1.2	11.4± .3	11.1± .5	12.2± .6	12.2± .9a	15.7±2.2ab	16.4± .6b	9.0±1.0	9.4±1.0	11.1±1.3
29	Sunny, wind	13.5± .6a	21.3±1.8b	20.4±1.5b	10.5±2.0	15.4± .6	13.7±1.7	12.7±1.1	17.2±3.6	18.4±2.8	6.7± .4a	8.1± .9ab	9.8± .3b
Apr 5	Sunny, mild	23.8±1.8	28.7±1.2	30.2±1.6	17.6±1.2	18.1±2.5	21.5±2.3	20.6± .5a	22.8±2.4a	30.4± .9b	11.6±1.1	14.9±1.4	15.3±2.0
14	Cloudy, wind	13.7± .6	12.0±2.1	13.6± .5	11.1± .5	12.0±1.1	11.4± .4	10.1± .3a	13.8±1.2b	12.1± .6b	9.4± .3a	11.0± .2b	11.9± .2c
19	Cloudy, wind	13.2±1.3	14.7±1.2	12.0±1.5	11.2± .7	12.4± .7	12.4±1.4	14.3± .8	15.3±1.5	14.7± .8	11.7± .9	14.2± .6	14.8±1.4
27	Sunny, mild	24.3± .5	25.5±3.1	26.5±2.4	18.5±2.0	16.9± .6	18.9±1.0	25.3±1.6	26.2±1.1	24.2±1.8	17.4±1.0	17.0±1.3	16.0±2.4

a–c Means with different letters, in subset, differ significantly ($P < 0.05$).

cm depth, +.47 and +1.39°C respectively. In the Douglas fir community, the average differences from the control plants were, for the clipped and burned plants at the 0 cm depth, +2.36 and +2.85°C respectively and at the 2.5 cm depth, +1.05 and +2.04°C respectively. In each case the temperatures were warmer in the burned plants. The average temperature difference between the clipped and burned plants were, in the big sagebrush community, .25 and .92°C at the 0 and 2.5 cm depth respectively and, in the Douglas fir community, .49 and .99°C at the 0 and 2.5 cm depth respectively.

The rates of plant growth in each treatment, and at weekly intervals, are shown in figure 3. After 27 April the rates of elongation were afffected by the development of inflorescence. It is evident that temperature markedly influenced growth to that time. This is confirmed in figure 4 using only estimates of average maximum air temperatures, made prior to 27 April, in regression analysis. The growth response to soil temperature at 2.5 cm was similar, however less variation was explained. The temperature-growth rate relationship was explained with linear equations for plants of the burn and clip treatments. For the control, however, the cubic polynomial was significant ($P<0.05$), accounting for an additional 4% of total variation. However, this model shows an upward inflection at the lower end of the scale thus making it unrealistic.

The regression coefficient describing growth of the

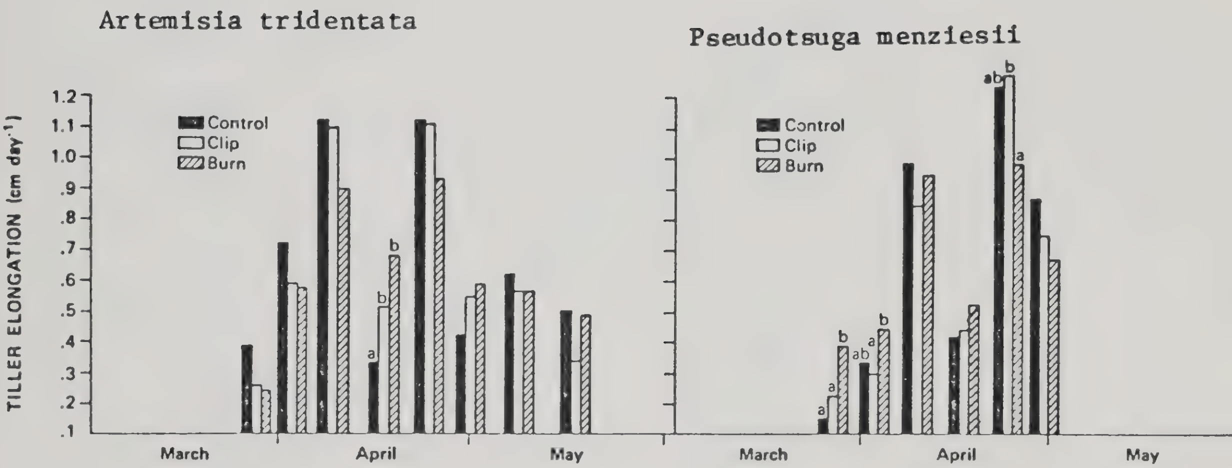

Figure 3. Mean daily rate of tiller elongation in bluebunch wheatgrass in two communities. Weekly treatment means with same letter, or no letter, do not differ significantly (P > 0.05).

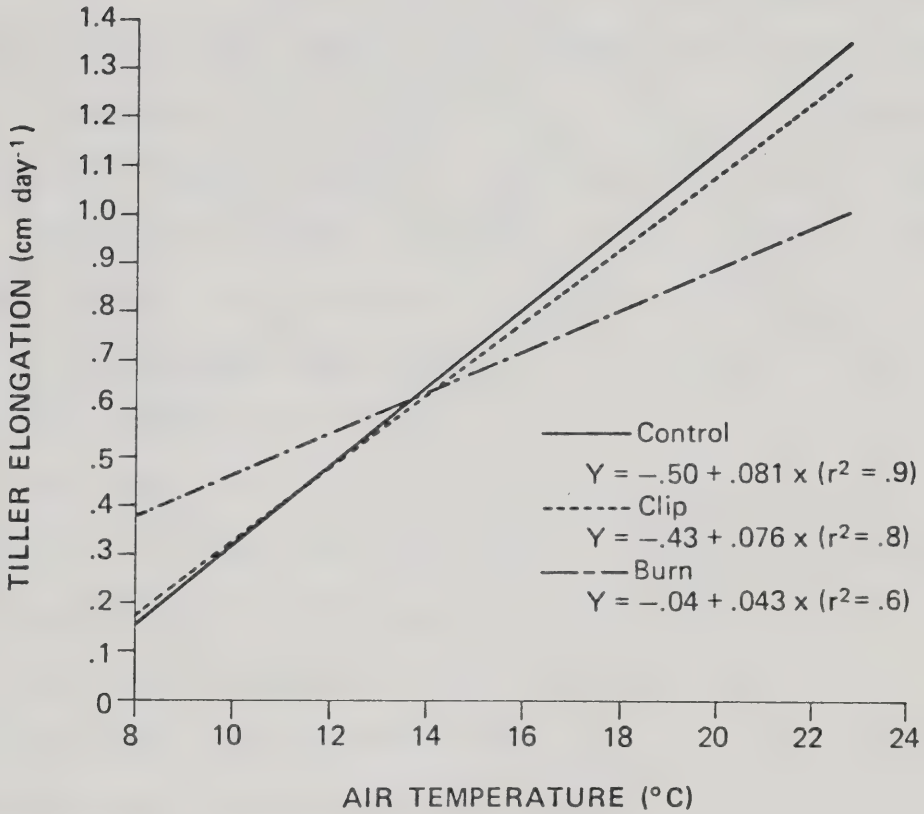

Figure 4. Effect of mean weekly air temperature (X), at 1.5 m above ground, on mean daily rate of tiller elongation (Y) (n=12).

burned plants (Fig. 4) differed significantly ($P<0.1$) from the coefficients describing growth of both the clipped and control plants. This contrast is also evident by an inspection of figure 3. Although few significant ($P<0.05$) differences occurred, it is evident that the growth rates of control and clipped plants were often more similar than any other combination with burned plants (Fig. 3). According to figure 4 the growth rates of the burned and control plants were the same at 13.5°C. Examination of figures 1 and 3 indicate that the points actually occurred between 10 and 12°C in the Douglas fir community and between 11 and 13°C in the big sagebrush community.

The rates of elongation, averaged for the period from 27 March to 10 May, were significantly ($P<0.05$) related to plant basal area for the control plants only. The best fit was a quadratic polynomial. The equations were: $Y=.262+.0132X-.0000525X^2$ ($R^2=.84$, $n=17$) in the big sagebrush community and $Y=.354+0.00389X-.0000067X^2$ ($R^2=.41$, $n=20$) in the Douglas fir community (Y=cm/day and X=cm^2). The slopes were near zero for both the burn and clip treatments. Similar ranges of plant sizes were recorded for each treatment, however, covariance analysis with area as a covariate was not attempted to examine the growth rates among treatments. The data did not meet a major assumption of covariance analysis, that the covariate effects be linear and the same among treatments (LeClerg _et al_. 1962).

3.2.2 Seasonal Effect of Burning on Growth

The height of mature foliage in the vicinity of the two burned areas was the same. At the November burn the average height (±1 SEm) was 39.0±1.2 cm and at the March burn the average height was 38.8±.7 cm. The height of spring growth (on 20 April) following burning differed significantly ($P<0.01$) for burning times. On the November burn the average height (±1 SEm) was 34.2±.9 cm and on the March burn it was 29.9±.6 cm.

3.2.3 Initiation of Spring Growth

Bluebunch wheatgrass initiated appearance of growth near the end of February in the big sagebrush community (Fig. 5). Appearance of growth at the ground surface was delayed for over 1 week in the Douglas fir community. Thereafter, the rate of elongation was similar to that of plants in the big sagebrush community. Previous fall regrowth was about 5 cm long and growing when spring initiated tillers first appeared at the crown. Before the newly formed tillers emerged above the soil the difference in length between the spring and fall initiated tillers had increased to 7.5 cm.

Tiller development was first noticeable at the crown of Sandberg's bluegrass in February in the big sagebrush community and one week later in the Douglas fir community. Emergence at the ground surface took from 2 to 3 weeks more. Crested wheatgrass was not sampled until 1 March. At this

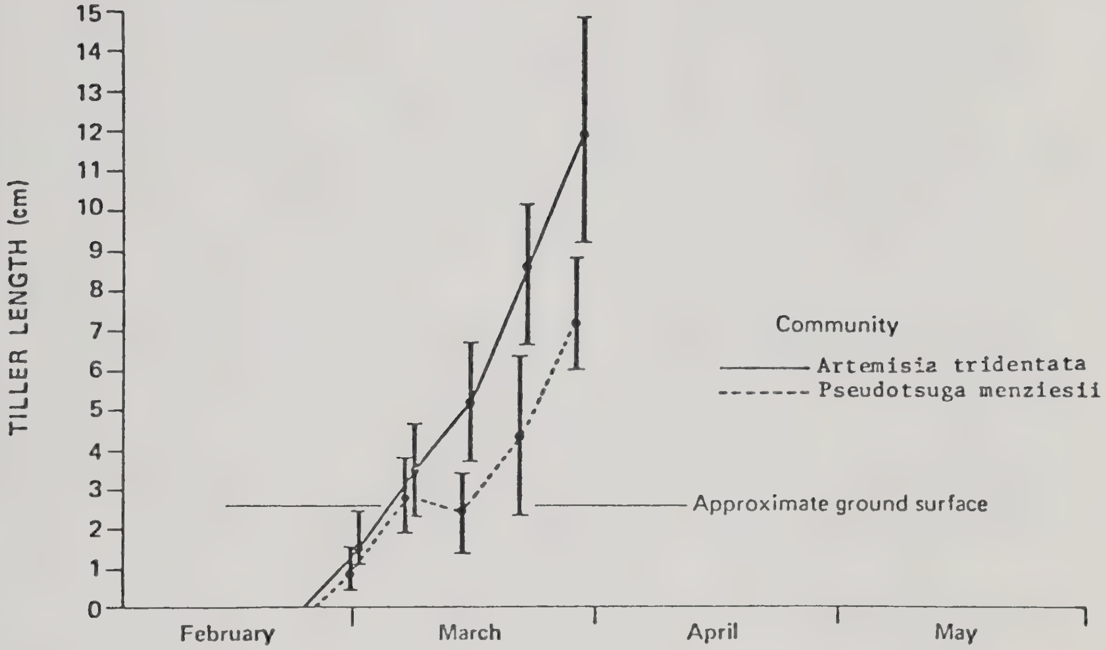

Figure 5. Appearance and accumulated growth of bluebunch wheatgrass tillers in two communities (weekly mean ± 1 SD).

time its development was similar to that of bluebunch wheatgrass.

3.3 Discussion

3.3.1 Plant Morphology

Litter removal by fall clipping or burning increased the productive potential of the plant to the second year through increased tillering (Tables 3 and 7). However, dry matter density, which is indicative of plant production, was not greater in defoliated plants until the second year (Tables 2 and 6).

The similarity of regression coefficients describing the relationships of volume to weight (Table 2) can be partly explained on the basis of tiller density and weight (Tables 3 and 4) which were negatively correlated ($r=-0.7$). The net effect (tiller weight x tiller density) was a general decrease in unit weight per plant on the burned treatment. Similar relationships of tiller weight to tiller density have been reported for reed canarygrass (*Phlaris arundinaceae*) and timothy (*Phleum pratense*) after clipping (Horrocks and Washko 1971). Mueggler and Blaisdell (1958) reported a first year decline in bluebunch wheatgrass productivity following burning.

A negative correlation of tiller weight and tiller density may be associated with the destruction by fire of carbohydrates at the crown, more rapid respiration of carbohydrates resulting from warmer temperatures at the

crown or the destruction of photosynthetic surface produced the previous fall. Trilica and Cook (1972) have shown that a significant proportion of carbohydrates may be stored in the stubble of crested wheatgrass. Furthermore, burning may destroy fall regrowth resulting in greater demand from the reserves and reduced photosynthetic area. McIlvanie (1942) reported that the compensation point, where depletion of carbohydrates ceases in bluebunch wheatgrass, occurs when the plant has reached 45% of its mature height.

Grazing in the first spring modified the treatment effect by removing tiller apices and photosynthetic area. However, the grazing impact was influenced by treatment. The height of standing litter was shown to exert a strong barrier effect to the grazer (Part II). Burning reduced the stubble to about 2 cm while clipping reduced the stubble to about 5 cm. This was reflected in the average spring grazing heights which, at heavy grazing pressure, were about 3 cm on the burned, 6 cm on the clipped and 9 cm on the control plots. The plant response immediately following grazing was likely determined by time, frequency and severity of grazing and by growing conditions.

Grazing by deer in April occurred at a crucial stage in the plants' development. It is probable that carbohydrate reserves were near minimal. Grazing in May would normally do less damage to the plant. At this time carbohydrate reserves are being replenished and storage is sufficient for regrowth. Insufficient moisture may be a crucial factor in

some years but evidently was not at the time of study (Broersma[5], 1978).

Regression coefficients, calculated only for plants of the cattle trials, (Table 5) do not indicate damage to the plant, nor does tiller density (Table 7). The larger coefficient for the burned plants in the big sagebrush community was probably the result of greater tiller density. Comparison of the coefficients between the big sagebrush and Douglas fir communities, reveals a completely opposite trend. This indicates that burned plants recovered more slowly in the Douglas fir community. The effect may be caused by less favorable growth conditions, such as shading and competition from trees for moisture and nutrients.

In the second year, growth of all plants occurred within mature foliage. The effect of standing litter on light and temperature would, therefore, be similar among treatments. This indicates that the measured effect was residual from the first year.

The trends observed among treatments for relationships of volume to weight and tillering were similar to those in the first spring after treatment. The only change measured was in the relationships of volume to weight in the Douglas fir community where the size of coefficient became similar among treatments. This indicates a loss of effect, confirmed by the similarity of tiller numbers among treatments in the second spring (Table 7). It is interesting to note that

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[5]Broersma, C. 1978. Personal communication.

tiller weights were similar among treatments in the second spring although tiller density was significantly (P<0.05) greater in clipped and burned plants. The net effect would be reflected in increased production from those plants. Daubenmire (1968) reviewed literature reporting similar observations for species other than bluebunch wheatgrass.

The tillering response to burning may be the result of warmer soil temperature (Langer 1963), increase in light intensity or removal of apical dominance by destruction of the previous fall regrowth. The latter effect does not appear to have been investigated. Destruction of tiller apices has resulted in increased tillering (Langer 1963) however these effects were in response to treatment during plant growth.

Plant regrowth is affected by available nutrients and environmental conditions (Youngner 1972). Although disputed, the level of carbohydrate reserves may also be a factor (Ogden and Loomis 1972). If that is so then, presumably, the number of tillers drawing from a fixed reserve will also affect their individual weight.

Fall grazing or burning also caused a redistribution of dry matter to a lower position in the plant. The treatment effect in the first growing season (Table 2), and the lack of effect in the second year (Table 6), indicates the response was due to light and temperature. Light and temperature in the plant are modified by standing litter. Burning defoliated the plants most and caused the greatest

effect in the first growing season after treatment. By the second year when no effect was measured, all new foliage grew within standing litter. The major difference observed was among trials and indicated a greater proportion of weight near the basal portion of plants grown in the big sagebrush community in April. This effect was probably the result of little or no culm development at the time of sampling.

The vertical distribution of weight within the plant is affected by the distribution of leaves on the culm, the number of leaves and the size of stems (Heady 1950). The vertical distribution of weight within the tiller also declines toward the apex. Knowledge of this relationship has been found useful for estimating utilization based on residual shoot length (Heady 1950).

3.3.2 Growth - First Spring after Treatment

The effect of burning on soil temperature was similar to that reported by Daubenmire (1968) for grassland fires. It appears the effect was largely the result of increased solar radiation at the crown since the difference between the clipped and burned plants was less than .5°C. The effect of burning was most noticeable at 2.5 cm. Perhaps greater evaporative cooling from burned soil kept temperature differences at the surface to a minimum.

Tiller elongation was most closely related to the maximum air temperature measured in a Stevenson screen.

Temperatures at ground level may be 5°C higher than at 1.5 m above ground level (Geiger 1966). The values used, therefore, to correlate with growth are somewhat below the maximum at the leaf. The temperature recorded in the soil may have been correlated better with tiller elongation if the effect were delayed. Soil temperature affects root elongation which in turn affects growth of the aerial portion.

The linear predictions of growth rate to temperature of the control and clipped plants was essentially the same. Although not shown was an inflection in the line (Fig. 4), to indicate that the optimum temperature for growth occurred near 20°C, a temperature considered optimum for most temperate species (Cooper 1970). The growth rate of burned plants differed from other treatments and showed a more variable response to temperature (Fig. 4). These effects may result from the destruction of fall regrowth thereby reducing the photosynthetic surface, from exposing the meristematic tissue to extreme soil temperatures or from increasing soil temperatures that may result in a moisture deficit.

4. PLANT CHEMISTRY

4.1 Methods

The treatment and sample collection and preparation in the first and second year after treatment were described in section 1. Plants representing each treatment of the May samples were randomly sorted into three groups of equal plant numbers. The segments of plants in each group were composited to yield four sub-samples according to vertical distribution (% height) in the plant (1) 0-20%; (2) 20-40%; (3) 40-60%; and (4) 60-100%. In order to reduce the number of samples for chemical analysis, the plant segments representing 0-20% and 40-60% were further composited across the groups of each treatment. Plants of the April samples were too small for separation beyond the segments. Only three sub-samples were composited for each treatment. They represented the vertical distribution (1) 0-20%; (2) 20-40%; and (3) 40-100%.

The samples were ground and analyzed for ADF (acid detergent fiber), NDF (neutral detergent fiber), lignin, nitrogen, calcium, phosphorus and magnesium. Nitrogen was determined by standard A.O.A.C. (1975) methods. NDF, ADF and lignin were determined by the methods of Goering and van Soest (1970) and modified by Waldern (1971). Phosphorus was determined by the vandomolybdo color method of Jackson (1958). Calcium and magnesium were determined by atomic absorption spectrophotometric methods based on the

techniques of Christian and Feldman (1970) and the Perkin-Elmer Corporation (1973). All methods were standardized by analyzing (1) standard reference samples of known concentrations and (b) duplicate samples. All results were converted, and reported, as percent of dry matter.

The chemical parameters of the May samples were statistically analyzed (with analysis of variance) among treatments, between segments (2nd and 4th) and between communities. The design was a 3 x 2 x 2 factorial and all interactions were examined. Separate analyses were made for each chemical constituent and for both first and second year since treatment. The vertical distribution of the constituents was described with linear equations for the April samples and with quadratic equations for the May samples. In the regressions, Y was the chemical constituent as percent of dry matter and X was the percent accumulated height to the mid-point of each individual or composited segment. The mid-points, for the April segments, were 10, 30 and 70% and, for the May segments, 10, 30, 50 and 80%.

4.2 Results

4.2.1 Forage Harvested in April

4.2.1.1 First Year after Treatment

Nitrogen, phosphorus and magnesium were greater in samples from the big sagebrush community, increased among treatments from the control to the burn and increased within the plant from the bottom to the top (Table 10). The

Table 10. First year effect of fall clipping or burning on the vertical distribution of chemical constituents (%) in bluebunch wheatgrass in two communities during April, 1977.

Community	Fall Treatment	Segment (% from plant base) 0-20	21-40	41-100	b_0	b_1
				Nitrogen		
At	Co	2.5	3.1	3.8	2.4	.022
	Cl	2.7	3.0	3.3	2.6	.011
	B	2.8	3.5	3.9	2.8	.017
Ps	Co	1.8	2.5	3.2	1.7	.022
	Cl	1.9	2.5	3.2	1.8	.022
	B	2.4	3.1	3.2	2.5	.012
				Calcium		
At	Co	.18	.24	.24	.19	.0009
	Cl	.22	.27	.30	.22	.0012
	B	.27	.29	.34	.26	.0012
Ps	Co	.26	.31	.31	.27	.0007
	Cl	.29	.35	.34	.30	.0007
	B	.35	.39	.45	.34	.0016
				Phosphorus		
At	Co	.38	.41	.44	.37	.0010
	Cl	.41	.43	.45	.41	.0006
	B	.41	.43	.44	.41	.0005
Ps	Co	.36	.37	.42	.34	.0010
	Cl	.39	.40	.42	.38	.0005
	B	.40	.39	.42	.39	.0004
				Magnesium		
At	Co	.18	.18	.18	.18	.0
	Cl	.18	.19	.20	.18	.0003
	B	.17	.19	.20	.17	.0005
Ps	Co	.12	.13	.14	.12	.0003
	Cl	.13	.14	.16	.12	.0005
	B	.15	.16	.17	.15	.0003
				NDF		
At	Co	69.6	65.3	60.8	70.4	-.14
	Cl	69.9	68.9	63.1	71.6	-.12
	B	67.1	65.4	61.3	68.2	-.10
Ps	Co	68.1	62.6	51.8	70.8	-.27
	Cl	61.8	64.1	54.2	65.3	-.14
	B	65.4	62.4	51.5	68.5	-.24
				ADF		
At	Co	34.6	32.9	30.8	35.0	-.06
	Cl	33.0	31.5	31.9	32.7	-.01
	B	33.3	38.3	30.3	36.6	-.07
Ps	Co	34.8	33.4	30.2	35.6	-.08
	Cl	30.6	36.3	28.9	33.8	-.05
	B	33.7	27.0	26.7	32.8	-.10
				Lignin		
At	Co	2.5	2.4	3.3	2.2	.015
	Cl	4.2	2.2	3.5	3.5	-.005
	B	3.3	5.8	5.2	3.8	.025
Ps	Co	2.2	2.8	4.5	1.7	.039
	Cl	2.8	6.9	.4	5.5	-.058
	B	6.9	6.3	1.9	8.2	-.087

b_0, b_1 Y-intercept and regression coefficient, respectively, of linear equations describing vertical change in the plant.

Co Control; Cl Clipped; B Burned.

At *Artemisia tridentata*; Ps *Pseudotsuga menziesii*.

community, treatment and plant relationships were opposite to those above for ADF and NDF and not consistent for lignin The response of calcium differed from the response of the first 3 elements only between communities.

4.2.1.2 Second Year after Treatment

Nitrogen increased, and NDF decreased, within the plant from the bottom to the top and among treatments from the control to the burn (Table 11). The plant and treatment relationships were not consistent for all other chemical constituents. Calcium, phosphorus and magnesium generally increased from the control to the burn while calcium and ADF decreased from the bottom to the top of the plant.

4.2.2 Forage Harvested in May

4.2.2.1 First Year after Treatment

Significant ($P<0.05$) differences were found among treatments, between the 2nd and 4th segments and between communities for all chemical constituents (Table 12). Treatment differences for the top segment in the big sagebrush community occurred only for NDF. Treatment effects were noticeable for most chemical constituents of all other segments. The vertical change of all constituents within the plant was generally least for the burned plants and most for the control plants (Tables 12 and 13). This generalization was demonstrated with a graphical display for nitrogen, phosphorus and NDF (Fig. 6).

Table 11. Second year effect of fall clipping or burning on the vertical distribution of chemical constituents (%) in bluebunch wheatgrass in the *Artemisia tridentata* community during April, 1977.

Fall Treatment	Segment (% from plant base) 0-20	21-40	41-100	b_0	b_1
			Nitrogen		
Co	1.9	2.5	3.1	1.8	.018
Cl	2.1	2.6	3.1	2.0	.016
B	2.3	2.9	3.1	2.3	.012
			Calcium		
Co	.41	.37	.39	.40	-.0002
Cl	.44	.41	.42	.43	-.0002
B	.50	.45	.40	.51	-.0016
			Phosphorus		
Co	.38	.37	.69	.28	.0056
Cl	.36	.35	.37	.35	.0002
B	.42	.41	.39	.42	-.0005
			Magnesium		
Co	.17	.15	.17	.16	.00007
Cl	.17	.17	.18	.17	.00018
B	.20	.18	.19	.19	-.00011
			NDF		
Co	67.9	64.8	56.9	70.0	-.185
Cl	65.8	59.0	54.4	66.3	-.179
B	64.0	55.1	53.2	63.3	-.161
			ADF		
Co	41.1	40.8	32.8	43.6	-.147
Cl	39.1	34.0	30.0	39.6	-.139
B	40.7	38.5	37.1	40.8	-.056
			Lignin		
Co	4.0	3.9	4.2	3.9	.004
Cl	2.3	2.0	.7	2.7	-.028
B	4.3	3.3	4.2	3.9	.002

b_0, b_1 Y-intercept and regression coefficient, respectively, of linear equations describing vertical change in the plant.

Co Control; Cl Clipped; B Burned.

Table 12. First year effect of fall clipping or burning on the chemical constituents (%) in the upper (4th and 5th) and lower (2nd) segments of bluebunch wheatgrass in two communities during May, 1977.

Community	Segment	Fall treatment: Control	Clip	Burn	Anova: Source	df	SS	F
				Nitrogen				
At	Top	2.34d	2.34d	2.37d	Treatment	2	.232	12.8*
	Bottom	1.58ab	1.73b	1.94c	Segment	1	3.635	399.5*
					Community	1	.247	27.1*
Ps	Top	2.26d	2.02c	2.38d	TxS	2	.043	2.4
	Bottom	1.56ab	1.47a	1.62ab	TxC	2	.086	4.7*
					SxC	1	.013	1.4
					TxSxC	2	.058	3.2
					Residual	24	.218	
				Calcium				
At	Top	.18ab	.21bc	.21bc	Treatment	2	.021	20.9*
	Bottom	.16a	.18ab	.22cd	Segment	1	.021	42.0*
					Community	1	.063	126.6*
Ps	Top	.29e	.29e	.38f	TxS	2	.0002	.2
	Bottom	.22cd	.23cd	.26de	TxC	2	.002	2.2
					SxC	1	.010	20.7*
					TxSxC	2	.004	4.2*
					Residual	24	.012	
				Phosphorus				
At	Top	.35ed	.34ef	.36fg	Treatment	2	.012	24.3*
	Bottom	.27a	.27a	.33de	Segment	1	.028	116.3*
					Community	1	.001	5.6*
Ps	Top	.33de	.31cd	.37g	TxS	2	.001	3.0
	Bottom	.26a	.28ab	.30bc	TxC	2	.0001	.2
					SxC	1	.0001	.2
					TxSxC	2	.003	5.6*
					Residual	24	.006	
				Magnesium				
At	Top	.15cd	.15cd	.14c	Treatment	2	.002	11.0*
	Bottom	.11ab	.12b	.15cd	Segment	1	.008	90.0*
					Community	1	.0007	8.5*
Ps	Top	.14c	.15cd	.16d	TxS	2	.0005	3.1
	Bottom	.10a	.12b	.11ab	TxC	2	.0003	1.7
					SxC	1	.001	13.4*
					TxSxC	2	.004	25.4*
					Residual	24	.002	
				NDF				
At	Top	63.8d	59.8bc	59.6b	Treatment	2	97.6	12.8*
	Bottom	71.3f	68.7e	63.7d	Segment	1	342.2	90.1*
					Community	1	124.7	32.8*
Ps	Top	59.2b	59.1b	55.7a	TxS	2	.6	.1
	Bottom	64.1d	63.1cd	63.3d	TxC	2	22.1	2.9
					SxC	1	4.1	1.1
					TxSxC	2	27.9	3.7*
					Residual	24	91.4	
				ADF				
At	Top	35.6cd	35.2bcd	33.9bc	Treatment	2	54.9	20.0*
	Bottom	42.4g	40.9fg	37.0de	Segment	1	342.2	249.4*
					Community	1	10.7	7.8*
Ps	Top	34.4bc	33.2b	30.9a	TxS	2	4.1	1.5
	Bottom	39.3f	41.7g	38.9ef	TxC	2	4.9	1.8
					SxC	1	8.8	6.4*
					TxSxC	2	18.2	6.6*
					Residual	24	32.9	
				Lignin				
At	Top	2.30a	3.20ab	2.70ab	Treatment	2	11.8	5.6*
	Bottom	6.76c	3.53ab	3.53ab	Segment	1	4.6	4.4*
					Community	1	1.3	1.3
Ps	Top	4.10b	4.20b	2.23a	TxS	2	9.1	4.4*
	Bottom	3.60ab	2.90ab	2.70ab	TxC	2	1.4	.7
					SxC	1	12.3	11.6*
					TxSxC	2	8.5	4.1*
					Residual	24	25.0	

a–g Mean chemical constituent with same letter within analysis do not differ significantly (P > 0.05).
* Significant at P< 0.05.
At *Artemisia tridentata*; Ps *Pseudotsuga menziesii*.

Table 13. First year effect of fall clipping or burning on the vertical distribution of chemical constituents (%) in bluebunch wheatgrass in two communities during May, 1977.

Fall Treatment	Artemisia tridentata			Pseudotsuga menziesii		
	b_0	b_1	b_2	b_0	b_1	b_2
			Nitrogen			
Co	.34	.0506	-.00032	.48	.0447	-.00028
Cl	.91	.0298	-.00015	.60	.0338	-.00020
B	1.23	.0307	-.00021	.78	.0304	-.00013
			Calcium			
Co	.13	.0012	-.000007	.20	.0005	.00001
Cl	.21	-.0023	.000028	.18	.0008	.000005
B	.22	-.0002	.000002	.26	-.0019	.00004
			Phosphorus			
Co	.20	.0020	-.000002	.23	.0015	-.000003
Cl	.27	.0004	.000007	.20	.0032	-.000023
B	.32	.0004	.000002	.26	.0011	.000003
			Magnesium			
Co	.08	.0012	-.000004	.10	.0001	.000006
Cl	.15	-.0018	.000022	.11	.0004	.000002
B	.18	-.0014	.000011	.12	-.0012	.000020
			NDF			
Co	73.3	-.195	.00051	69.4	-.210	.00106
Cl	71.6	-.042	-.00130	67.2	-.065	-.00041
B	67.0	-.048	-.00051	65.3	-.018	-.00127
			ADF			
Co	52.4	-.394	.00231	46.4	-.275	.00157
Cl	47.1	-.238	.00111	43.6	.056	-.00228
B	43.4	-.165	.00063	42.5	-.124	-.00027
			Lignin			
Co	9.82	-.1366	.00052	4.28	.0243	-.00030
Cl	6.34	-.1000	.00077	5.80	-.1511	.00163
B	7.09	-.1854	.00162	3.41	.0073	-.00026

b_0, b_1, b_2 Y-intercept and the first and second partial regression coefficients, respectively, of quadratic equations describing vertical change in the plant.

Co Control; Cl Clipped; B Burned.

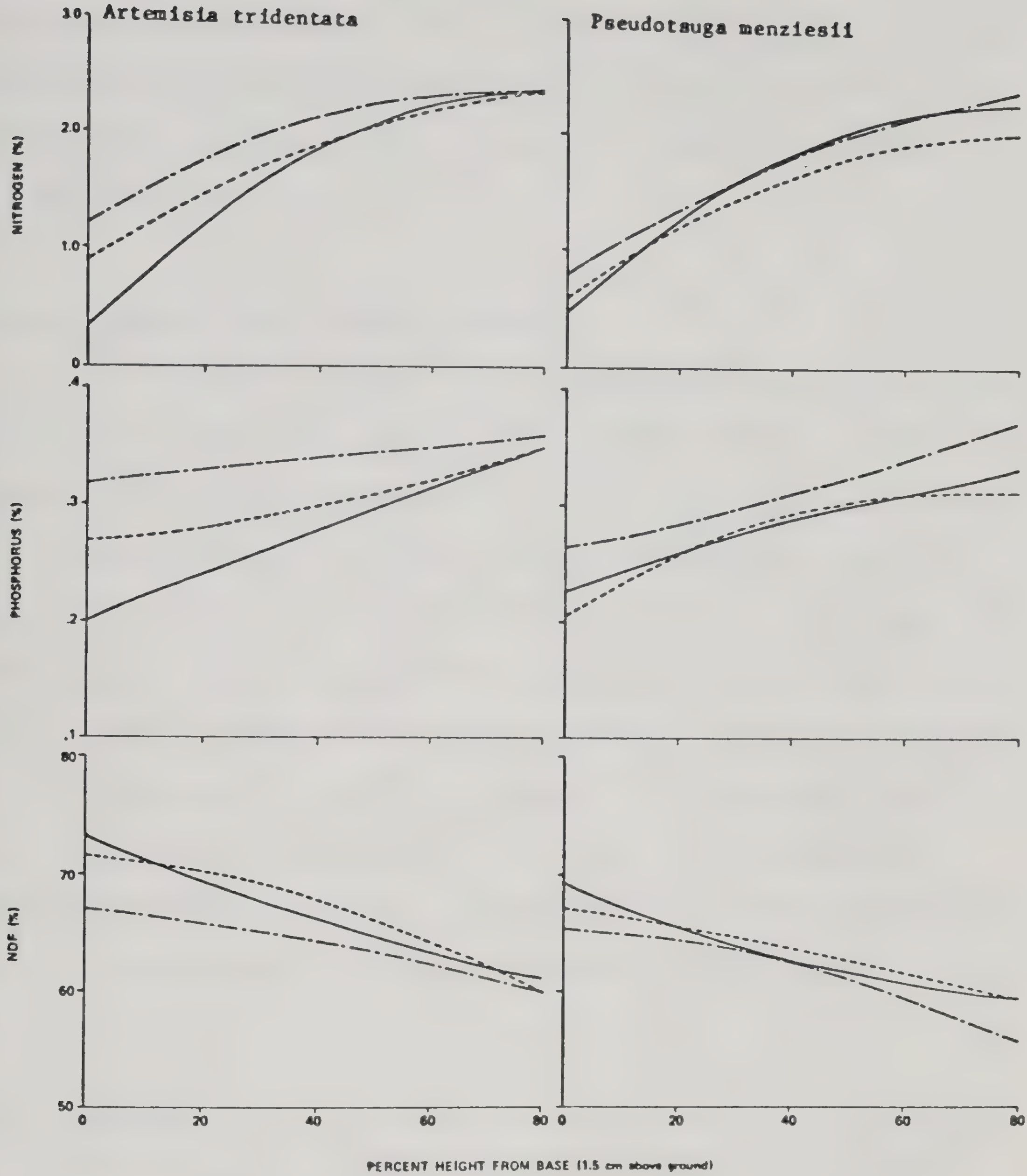


Figure 6. The vertical concentration (%) of nitrogen, phosphorus and NDF, in bluebunch wheatgrass from three treatments (control, ——; clip,-----; burn,—·—) and in two communities during May.

The elements, nitrogen, calcium, phosphorus and magnesium increased and the fibrous components, NDF, ADF and lignin decreased with increasing plant height (Tables 12 and 13) and from plants of the control to plants of the burn treatment (Table 12).

4.2.2.2 Second Year after Treatment

The treatment effects were reduced from the first year (Table 14). This was particularly evident in the bottom segment where few significant ($P<0.05$) differences occurred. The reduced treatment effect was also associated with less consistent response among treatments. In the first year, the chemical gradient changed from the control to the burn (Table 12). In the second year, however, the graze treatment was represented by either the high or low chemical value in the majority of comparisons (Table 14). The diminished treatment effect was also reflected in a greater similarity of regression equations among treatments (Table 15).

4.3 Discussion

The ultimate criteria for measuring forage quality is consumer output normally measured as red meat produced. Direct measurment of output is prohibitive because it is costly, time consuming and the results have a narrow range of applicability. For example, red meat produced will vary with species and even breed of animal. Consequently, most attempts to quantify forage quality rely on measuring

Table 14. Second year effect of fall clipping or burning on the chemical constituents (%) in the upper (4th and 5th) and lower (2nd) segments of bluebunch wheatgrass in two communities during May, 1977.

Community	Segment	Fall treatment: Control	Clip	Burn	Anova: Source	df	SS	F
				Nitrogen				
At	Top	1.99f	2.08f	2.04f	Treatment	2	.28	22.4*
	Bottom	1.46bc	1.53bcd	1.59cde	Segment	1	2.49	390.2*
					Community	1	.62	98.0*
Ps	Top	1.69e	2.04f	1.64de	TxS	2	.03	2.2
	Bottom	1.11a	1.44b	1.20a	TxC	2	.18	14.1*
					SxC	1	.002	.3
					TxSxC	2	.002	.1
					Residual	24	.15	
				Calcium				
At	Top	.21a	.27bc	.29c	Treatment	2	.008	4.3*
	Bottom	.20a	.24abc	.28c	Segment	1	.000	.0
					Community	1	.002	1.9
Ps	Top	.25abc	.28c	.22ab	TxS	2	.004	2.1
	Bottom	.24abc	.24abc	.24abc	TxC	2	.012	6.8*
					SxC	1	.000	.4
					TxSxC	2	.001	.3
					Residual	24	.021	
				Phosphorus				
At	Top	.36f	.35ef	.37f	Treatment	2	.002	1.81
	Bottom	.28cd	.31cde	.32def	Segment	1	.024	41.3*
					Community	1	.056	98.4*
Ps	Top	.27bc	.27bc	.28cd	TxS	2	.001	.8
	Bottom	.22a	.23ab	.23ab	TxC	2	.000	.2
					SxC	1	.000	.5
					TxSxC	2	.000	.4
					Residual	24	.014	
				Magnesium				
At	Top	.16e	.18f	.16e	Treatment	2	.0002	1.0
	Bottom	.13cd	.15de	.15de	Segment	1	.0047	33.6*
					Community	1	.0191	137.7*
Ps	Top	.12bc	.13cd	.11abc	TxS	2	.0007	2.5
	Bottom	.10ab	.09a	.10ab	TxC	2	.0007	2.6
					SxC	1	.0000	.2
					TxSxC	2	.0000	.1
					Residual	24	.003	
				NDF				
At	Top	66.1bc	61.1a	67.0cde	Treatment	2	53.7	9.7*
	Bottom	69.8e	66.4bcd	68.2cde	Segment	1	104.7	37.6*
					Community	1	7.6	2.7
Ps	Top	67.5cde	63.8ab	65.7bc	TxS	2	19.8	3.6*
	Bottom	68.6cde	69.4de	69.0de	TxC	2	17.3	3.1
					SxC	1	.0	.0
					TxSxC	2	8.4	1.5
					Residual	24	66.6	
				ADF				
At	Top	39.9a	39.3a	41.2abc	Treatment	2	18.4	5.6*
	Bottom	43.8d	42.0bcd	43.8d	Segment	1	68.9	42.0*
					Community	1	2.0	1.2
Ps	Top	40.2ab	40.4ab	42.1bcd	TxS	2	1.7	.5
	Bottom	43.1cd	42.8cd	44.3d	TxC	2	2.3	.7
					SxC	1	.9	.5
					TxSxC	2	.2	.1
					Residual	24	39.4	
				Lignin				
At	Top	4.50a	4.40a	5.63a	Treatment	2	5.3	1.9
	Bottom	3.93a	3.73a	5.06a	Segment	1	.4	.3
					Community	1	.4	.3
Ps	Top	4.02a	4.06a	4.43a	TxS	2	1.2	.4
	Bottom	3.43a	5.20a	4.63a	TxC	2	3.0	1.1
					SxC	1	1.4	1.0
					TxSxC	2	2.5	.9
					Residual	24	33.9	

a-g Mean chemical constituent with same letter within analysis do not differ significantly ($P > 0.05$).

* Significant at $P < 0.05$.

At *Artemisia tridentata*; Ps *Pseudotsuga menziesii*.

Table 15. Second year effect of fall clipping or burning on the vertical distribution of chemical constituents (%) in bluebunch wheatgrass during May, 1977.

Fall Treatment	Artemisia tridentata b_0	b_1	b_2	Pseudotsuga menziesii b_0	b_1	b_2
			Nitrogen			
Co	.38	.0455	-.00032	.18	.0364	-.00022
Cl	.49	.0376	-.00022	.24	.0476	-.00032
B	.57	.0407	-.00028	.19	.0428	-.00031
			Calcium			
Co	.09	.0042	-.000035	.07	.0070	-.000060
Cl	.15	.0032	-.000022	.16	.0030	-.000018
B	.17	.0042	-.000035	.09	.0071	-.000068
			Phosphorus			
Co	.20	.0030	-.000013	.08	.0055	-.000039
Cl	.21	.0031	-.000017	.14	.0035	-.000023
B	.22	.0038	-.000024	.13	.0038	-.000024
			Magnesium			
Co	.09	.0010	-.000002	.04	.0023	-.000017
Cl	.13	.0004	.000003	.07	.0007	.000001
B	.09	.0025	-.000021	.04	.0025	-.000021
			NDF			
Co	72.2	-.096	.00024	75.7	-.397	.00364
Cl	72.5	-.246	.00129	73.2	-.086	-.00036
B	80.5	-.471	.00384	71.5	-.086	.00017
			ADF			
Co	46.8	-.091	.00006	48.9	-.239	.00163
Cl	45.8	-.116	.00046	48.0	-.189	.00118
B	47.4	-.142	.00080	47.5	-.105	.00048
			Lignin			
Co	5.87	-.076	.00075	7.00	-.187	.00189
Cl	6.57	-.151	.00154	5.98	-.066	.00051
B	4.03	.022	-.00004	5.85	-.070	.00065

b_0, b_1, b_2 Y-intercept and the first and second partial regression coefficients, respectively, of quadratic equations describing vertical change in the plant.

Co Control; Cl Clipped; B Burned.

properties which are indirectly related to consumer output. Mott and Moore (1969) define forage quality in terms of its nutritive value and quantity consumed. The nutritive value of forage is described, in turn, by its chemical composition, digestibility and nature of digested products. It can be seen that the chemical properties reported in this paper are considerably removed from the ultimate measurement of forage quality. They may, however, be used as an index to compare forages and to predict benefits to the herbivore.

4.3.1 Effects of Fall Clipping or Burning on Plant Chemistry

The first year effects of burning raised the mineral concentration and decreased the proportion of cell wall in the foliage both in April and May. Daubenmire (1968) cites published information on warm season grasses showing similar responses to burning. The effect has been suggested to be caused by an enrichment of soil nutrients from the ash, an increase in microbial activity releasing greater quantities of nutrients into the soil and an increase in root activity causing greater uptake of nutrients (Mes 1958, in Daubenmire 1968). Burning has also been reported to increase the *in vitro* digestibility, crude protein and phosphorus content of native range in Arizona (Pearson *et al*. 1972) and crude protein in bluebunch wheatgrass (Uresk *et al*. 1976).

Mineral and fiber constituents in plants of the clipped treatment (first year after treatment) were often intermediate to those of the burn and control. In an earlier

study (Willms *et al.* manuscript in preparation) higher mineral but lower cell wall constituents were observed in the March and April samples of fall grazed plants than in fall ungrazed plants of bluebunch wheatgrass. These results were similar to the April samples of the present study but differed from the May samples largely in the cell wall components.

The treatment effect persisted into the second year (Tables 11 and 14) although spring grazing was imposed in the year prior to sampling. Visual examination of the April data (Tables 10 and 11) shows consistency in the trends for concentration of nitrogen, phosphorus, magnesium and the fibrous components, among treatments and segments. In the May data, however, several noteworthy changes occurred (Tables 12 and 14). First, the treatment effect was markedly reduced for all constituents. Second, the order of magnitude for nitrogen shifted to favor greater concentrations in the clipped forage. Third, the order of magnitude for NDF shifted to favor smaller proportions in the clipped forage.

The effect of differing grazing behaviors between deer and cattle on plant chemistry is not clear. Although cattle remove mature foliage and deer leave it, post-grazing regrowth created a similar environment among treatments in the next year. The effects at that time were, therefore, believed to be residual from the treatment and time of grazing.

Comparisons of treatment effects on the concentration

of chemical constituents between habitats should not be made because of the delay in sampling time. It is evident, however, that the nutrient distribution within the plant and among treatments were similar.

4.3.2 Vertical Distribution of Nutrients and Cell Wall Constituents

Factors affecting the vertical distribution of chemical constituents are the length of internode on the culm, the variability among tiller lengths within a plant and the stage of phenological development. The internode length affects the distribution of leaves on the tiller and the proportion dry matter of leaves to stem. Thus, chemical variation between them affects the vertical distribution of chemistry in the tiller and in the plant. Phenological development affects the distribution of chemistry by defining the length of internodes, thereby determining the culm to leaf ratio, and the sites of nutrient accumulation and depletion. Nitrogen, phosphorus and magnesium accumulate at sites of meristematic activity which occurs in the tiller primarily at the apex and base of new leaves. Since new leaves originate at the apex, the chemical gradient is reinforced

The fibrous components of the plant, NDF, ADF and lignin, decrease with increasing plant height in relation to decreasing tissue maturity and decreasing culm to leaf ratio. The secondary wall of the plant cell is formed after

cell enlargement (Allinson 1969), hence formation is directly related to maturity which decreases with increasing plant height. The leaves have less fiber than the stem in Rhodes grass (Chloris gayana) and Pangola grass (Digitaria decumbens) (Goto and Minson 1977) and, presumably, in bluebunch wheatgrass. The culm to leaf ratio decreases with increasing plant height as a result of shortening internodes. The method of dissection also contributed to this relationship. Since the leaves were held parallel to the culm, their proportion of dry matter increased and, at the top, was the only material represented.

Deviations from the general distribution of fibrous constituents in the cell occurred mainly with lignin. Although sample preparation and analysis may be faulted, other sources of variation were also present. One was the variable development of inflorescence and their contribution to the sample. Another was the proportion of plant parts represented in each segment. For example the segment containing the basal portion of leaves, with meristematic tissue, would be newer material than further up the leaf. A third variable was the interaction of nitrogen with lignin formation. Reid et al. (1967, in van Soest 1969) report greater lignification in sudan grass (Sorghum vulgare var. sudanese) fertilized with nitrogen which may offset the nutritive benefits of higher nitrogen levels. Similar observations on ryegrass (Lolium sp.) have been reported by Deinum (1966a, in van Soest 1969).

The effect of the fibrous constituents on dry matter digestibility (DDM) have been described by van Soest (1967) in the equation: $DDM = .98(100-X)-12.9+X(1.473-0.789\log L)$ where X is percent NDF and L is the percent lignin in ADF. According to this equation the digestibilities among segments tended to decrease with increasing plant height. Only for samples taken in May, (first season after treatment) from the big sagebrush community did digestibility increase consistently among treatments to the fourth segment.

The significance of these changes are difficult to assess. Certainly, the predication itself is fallible for intra-plant comparisons since not only lignin content but also the distribution of lignin in the plant cell affects dry matter digestibility (Allinson 1969; van Soest 1969). Although no evidence was found in literature, differences in lignin distribution between the cell of a culm and leaf should be expected because of their different structural function.

On the basis of information available, a well defined digestiblity gradient within the plant cannot be established. In the April samples, a gradient of decreasing digestibility with increasing plant height is reasonable since the tiller apex is near the ground level and the leaf tips are the oldest plant parts. By May the tillers have elongated and the youngest, less fibrous plant parts are at the top, thus resulting in a gradient of increasing

digestibility to the plant apex.

4.3.3 Importance of Chemical Change on the Herbivore

Fall grazing or burning tended to improve forage quality although benifits to the herbivore are doubtful. Minerals were often similar among treatments near the top of plants (Tables 10,11,12,14) and, in most cases, adequate throughout the plant for all classes of livestock. The effect of fall defoliation on the animal, through chemical change, was most important near the base of the plant.

Fall grazing or burning had a negligible effect on the nutritional status of deer in April and cattle in May. NDF, which gives a good prediction of voluntary intake (van Soest 1965; Rohweder *et al*. 1978), varied slightly, and with no consistency, among treatments in April (Table 10). Voluntary intake by cattle may be expected to increase slightly from the control to the burn treatment. The predicted increase (van Soest 1965) is from 60 to 63 gm/kg body weight^{75} where the choice is from the top of the plant and from 51 to 60 gm/kg body weight^{75} where the choice is from the bottom of the plant (Table 12).

Crude protein (%N x 6.25) requirements of deer can be met by selective feeding from all treatments. Verme and Ullrey (1972) suggest that 17% crude protein is adequate for growing fawns and lactating does. This requirement was not met in the control and clipped treatments below 40% of plant height in the Douglas fir community and below 20% of plant

height in the big sagebrush community (Table 10). By comparison, the maintenance requirements for beef cattle (N.R.C. 1970) could be met by all green forage. However, predicted crude protein intake is 2.3 gm/kg body weight^{75} greater in burned plants than in control plants. This would permit a daily weight gain of about .25 kg in young animals (N.R.C. 1970)>

Carlier *et al*. (1976) have developed linear relationships for ryegrass (*Lolium multiflorum* and *L. perenne*) between percent digestible crude protein (Y) and percent crude protein (X) in the equation: Y=.84X-2.43. This implies a digestion coefficient that varies in a curvilinear manner, increasing from low to high levels, with the percent crude protein in forage. If ryegrass and bluebunch wheatgrass are similar, according to this equation, crude protein in the lower segment of the control plant was about 24% less digestible than crude protein in the same position in the burned plant (Table 12).

The concentrations of phosphorus and magnesium were adequate in forages of all treatments to meet deer and cattle requirements (Tables 10,11,12,14). Calcium, however, was generally deficient in forages the first year after treatment. The calcium and phosphorus requirements for white-tailed deer (*Odocoleus virginianus*) fawns are .40% (Ullrey *et al*. 1973) and .28% (Ullrey *et al*. 1975) respectively. The same requirements for lactating cows are .28% and .23% repectively (N.R.C. 1970). The calcium

deficiency contributed to a ratio of calcium to phosphorus that was below the minimum recomended level of 1:1 for both domestic livestock (Maynard and Loosli 1969) and white-tailed deer fawns (Ullrey *et al*. 1973). Burning increased the concentration of both calcium and phosphorus. Burning also tended to increase the ratio of calcium to phosphorus but not sufficient to meet the minimum requirement.

According to the equation by Waldern (1972), all forages had adequate digestible energy to meet the most stringent animal requirements. Digestible energy did not appear to vary among treatments in April (Table 10) and varied moderately among treatments in May (Table 12). The difference in April should not affect voluntary intake of digestible energy in deer (Ammann *et al*. 1973) and in May affect a maximum change of 1.9 $Kcal/Kg^{75}$ in cattle (from information provided by van Soest, 1965 and Waldern, 1972).

Part 2

TREATMENT EFFECTS ON THE ANIMAL

5. FORAGE PREFERENCES AND FORAGING STRATEGY

5.1 Methods

5.1.1 First Year after Treatment

Four selection trials, two in each community were made with deer and four with cattle. The trials with deer were made in April (1976) and those with cattle were made in May (1976). The trials with both deer and cattle were conducted in a similar spatial and chronological order. The first trial was made in the big sagebrush community and the second, following within one week, was made in the Douglas fir community. The procedure was repeated in one or two weeks to conclude each set of trials. The same three animals were used throughout. The deer were two adult does and one juvenile buck while the cattle were all adult females.

The plots of every trial were arranged in a 3 x 3 Latin square with four squares. This design was used to provide the necessary replication while constraining the maximum number of consecutive plots, with the same treatment, to two. Plot dimensions were 1.25 m x 5 m for the deer trials and 2.5 m x 10 m for the cattle trials. The dimensions of each square in the deer trials was 3.75 m x 15 m and for the cattle trials 7.5 m x 30 m. The squares were positioned so that the total dimensions were 15 m x 15 m for the deer trials and 30 m x 30 m for the cattle trials. For the deer trials, the plot perimeters were enclosed with fishnet to a height of 1.75 m according to the method described by Willms

et al. (1978). The cattle sites were surrounded with a 3-stand barbed wire fence.

Clipping and burning were done in October, 1975. Clipping was done with a rotary lawnmower and electric powered sickle. The latter tool was used in areas inaccessible to the mower. The stalks were allowed to lie where they fell. Burning was done when the relative humidity, measured at the Kamloops airport, averaged 42% and the temperature averaged 9.8°C. These weather conditions permitted good control of the fire although individual plants had to be ignited. This was done either by spreading burning embers or lighting with a kerosene fueled drip torch.

Selection trials in the spring were preceded by a conditioning period of one week. Deer were placed in enclosures adjacent to the trial while cattle were permitted to graze adjacent fields. Water was provided *ad libitum* throughout the conditioning and trial periods. A pelleted ration (Buckerfields Dairy Ration), consisting of oats, barley and corn with soybean and mineral supplement, was provided the deer during the conditioning period. The ration was removed the night prior to the trial. Regelin *et al*. (1976) found that feeding a supplement to tame deer did not affect their selection of native forage.

Forage selection was observed by both direct and indirect methods. Direct observations were made by one observer, with tape recorder, assigned to each animal. The

tape recorder was engaged while the animal was searching and ingesting forage. The number of bites from each forage species were recorded by plot. A bite was counted each time forage was prehended and removed. The time spent feeding in each plot was measured when the tapes were transcribed. The animals were observed at three discrete periods in every trial. Thus each period of observation yielded information on animal response to the treatments at varying levels of utilization. The time and duration of each period was dictated by animal activity. The first observation of every trial began about 7:00 a.m. when the animals were introduced into the study area. Intense feeding for about one hour in early morning was followed by a period of rest. Feeding in late morning and afternoon was sporadic, lasting for 15 to 30 minutes. The period of observtion was extended to accommodate a single individual who was feeding, or contracted when all animals were inactive.

Indirect observations of forage utilization, selection and relative preferences were made only on green forage of bluebunch wheatgrass. Permanent 1-m^2 sub-plots were established in each plot. Single sub-plots were centrally located in one randomly selected quadrat on the deer plots and one in each half of the cattle plots. The latter approach reduced the time for relocating the sub-plots. All bluebunch wheatgrass plants were mapped onto a grid and measured one day prior to the start of the trial (Survey 0). Plant measurements consisted of the circumference near

ground level and an estimate of plant height taken as the average of the tallest tillers. Surveys to estimate utilization were made two or three times during the trial. One survey was made after each period of direct observation. Utilization estimates were made from measurements of residual tiller length and estimates of the proportion of plant area grazed.

In order to relate plant measurements to dry weight, polynomial regressions of weight to plant volume and percent accumulated weight to percent accumulated height were calculated from 20 or more control plants. The plants were selected according to size, shape and basal uniformity. The bases of selected plants were round and tillers were distributed throughout. The circumference and height of each plant were measured, as above, by the same person to reduce variation. The plants were then clipped at 1.5 cm, sorted according to mature and green forage, dried at 65°C and weighed. The majority of intact tillers were then aligned at the basal end and segmented into five parts, according to 20 percent of the measured height less 1.5 cm. The parts were dried, weighed and converted to percent of total weight of all parts.

Plant volume was calculated as a cone. Regressions describing plant weight (Yv wt.) on plant volume (Xv) and proportion accumulated weight (Yh wt.) on proportion accumulated height (Xh) were tested for significance ($P<0.05$) to the 3rd degree polynomial according to Goulden

(1952). The X and Y coordinates of 0,0 and 1,1 were entered with each data set thus forcing the regressions near those points. Definition of the 0,0 and 1,1 coordinates justifies their membership in the data set.

The initial weight of green bluebunch wheatgrass in each sub-plot was estimated as: $\sum_{i=1}^{n}$Ywt.i where Ywt.i is the weight of the ith plant in the sub-plot having n plants. Residual forage at survey j in each sub-plot was estimated as: $\sum_{i=1}^{n}$[Ywt.i * Yp wt.ij + [(Ywt.i - (Ywt.i * Yp wt.ij)) * ((100-Xa ij)/100)]], where Yp wt.ij is an estimate of the proportion weight of plant i remaining at survey j. and modified by the percent proportion of plant area (Xa ij) which was grazed at survey j. Utilization in each sub-plot at the first survey was estimated as: $\sum_{i=1}^{n}$(Ywt.i-residual i,j=1) and utilization at each survey, from j=1 to j=m-1, thereafter as: $\sum_{i=1}^{n}$(residual i.j-residual i,j+1) where m is the total number of surveys made.

Forage selection was expressed, in percent, as the weight utilized from a treatment to the weight utilized from all treatments. Relative preference of each forage class was calculated as the proportion utilized divided by the proportion available. The proportion utilized was the quotient of the forage selection term and was estimated for between surveys j and j+1. The proportion available was estimated from survey j (survey j increments by 1 to m-1).

The time required per bite was estimated from the total number of bites taken from all forage species and from the

total time the animals were actively foraging. Separate calculations were made for each treatment. The weight per bite was estimated only for between surveys 0 and 1 since the bite count for this period was virtually complete. The weight was an estimate of total utilization from the plots of each treatment. In addition, an estimate of the weight per bite relative to the control could be made for each additional observation despite an incomplete count. This was done with the assumption that bites not counted were distributed in the same proportion among treatments as those that were counted.

5.1.2 Second Year after Treatment

Observations in the second year after treatment (1977) were made in the same months and at the same sites as in the first year, with one exception. Constraints on time and increasing irritability among animals prevented observations to be made on deer in the Douglas fir community. Furthermore, personal observations on free ranging deer have shown that the treed communities on the lower ranges were occupied primarily for their cover qualities while the open communities were occupied for their forage qualities. These conditions minimize the importance of a clipping or burning effect in the second year after treatment.

The sequence in which the trials were made was modified from the first year. Rather than alternating between communities and dispersing them through the month, a

duplicate set of trials in each community was made simultaneously or in immediate succession. The trial sites for deer were contiguous which enabled them to be combined. The trial sites for the cattle were separate and observations at each were made individually.

The second year treatment effects were studied using four animals of each species. The cattle were yearling females while the deer were one and two year old, males and females. The animals were conditioned for several weeks in enclosures adjacent to the sites. They were provided water ad libitum and the deer were also provided with a pelleted ration (Buckerfields Dairy Ration). The ration was removed one day before the trial.

Forage utilization, selection and relative preferences were observed indirectly on the plant as in the first year. The deer and cattle were observed both for a total of four days in the big sagebrush community and the cattle were observed for a total of three days in the Douglas fir community.

Estimates of availability and utilization of green forage were made as described earlier. Calculations of the relationships of volume to weight and of height to weight were modified, somewhat, by describing plant volume as a cylinder and by forcing the regression lines through the lower and upper coordinates by statistical methods (Greig and Bjerring 1977). These calculations were made for plants from each treatment (Part I, Section 1).

Availability, but not utilization, estimates were made for one year old weathered forage. Weathered forage represents the post-grazing regrowth in the first spring after treatment. It was assumed that deer did not utilize this forage. Consumption of weathered forage by cattle may be estimated by assuming it was utilized in the same proportion, of initial plant weight, as green forage. Some utilization estimates of weathered forage were made and correlated with the utilization of green forage to test that assumption.

Treatment differences of availability and utilization parameters were tested using analysis of variance. The variation was partitioned according to Federer (1955) for a Latin square design having more than one square. The rows, columns and squares were tested as a source of variation for bites by individual animals in observation 1, for the first year after treatment, and for the degree of utilization at each survey in both years. Duncan's multiple range test (LeClerg *et al*. 1962) was used to test for significant differences ($P<0.05$) among averages.

5.2 Results

5.2.1 First Year after Treatment

Initial availability of bluebunch wheatgrass was similar among treatment in the deer trials (Table 16). In the cattle trials, however, availability in the clipped and burned treatments was less than in the control (Table 17).

Table 16. Effect of fall clipping or burning on bluebunch wheatgrass availability and its utilization by deer in relation to average grazing intensity in two communities during April, 1976 (n=12).

Mid-April				Late April			
Control	Clip	Burn	Grazing intensity+	Control	Clip	Burn	Grazing intensity
			Artemisia tridentata				
			Available Forage				
6.7 ±0.9a*	5.9±1.0a	4.4±0.7a	0	7.2 ±1.1a	7.1±1.5a	7.4±1.4a	0
			Forage Utilized				
0.02±0.02a	0.7±0.2a	2.4±0.5b	19	0.01±0.01a	0.5±0.2ab	1.8±1.0b	11
0.2 ±0.1a	1.2±0.2b	1.1±0.2b	33	0.4 ±0.1a	2.6±0.8b	2.8±0.5b	38
0.5 ±0.1a	0.7±0.2a	0.7±0.1a	44	1.1 ±0.2a	1.1±0.2a	1.5±0.6a	55
			Pseudotsuga menziesii				
			Available Forage				
2.0 ±0.2a	2.1±0.2a	1.6±0.2a	0	3.7 ±0.5a	3.6±0.4a	3.5±0.4a	0
			Forage Utilized				
0.01±0.00a	0.3±0.1b	0.8±0.2c	20	0.01±0.01a	0.6±0.1b	1.0±0.4b	15
0.1 ±0.02a	0.4±0.1ab	0.6±0.2b	39	0.03±0.02a	0.4±0.1ab	0.8±0.2b	27

\+ Calculated as: (Total utilization ÷ Total available)x 100.
* $gm/m^2 \pm 1$ SEm.
a–c Means in row, at each time, followed with the same letter do not differ significantly ($P > 0.05$).

Table 17. Effect of fall clipping or burning on bluebunch wheatgrass availability and its utilization by cattle in relation to average grazing intensity in two communities during May, 1976 (n=12).

Early May				Late May			
Control	Clip	Burn	Grazing intensity+	Control	Clip	Burn	Grazing intensity
			Artemisia tridentata				
			Available Forage				
70.4±4.5c*	42.6±5.3b	27.9±3.4a	0	88.6±8.3b	61.8±8.8a	47.5±10.1a	0
			Forage Utilized				
0a	14.8±3.2b	14.8±2.1b	21	1.6±1.4a	24.7±3.8b	27.7±5.8b	27
0.9±0.5a	6.9±1.6b	6.0±1.1b	31	8.0±2.4a	8.8±2.2a	9.8±3.0a	41
25.4±3.2b	6.0±1.6a	2.2±0.8a	55	28.0±3.3c	11.3±2.4b	3.5±1.0a	62
			Pseudotsuga menziesii				
			Available Forage				
33.5±2.2a	28.3±3.3a	27.8±3.8a	0	46.2±8.4b	21.6±4.8a	26.0±4.5a	0
			Forage Utilized				
0.2±0.1a	18.0±2.3b	20.7±2.7b	43	0.02±0.01a	13.1±3.0b	16.5±2.9b	33
4.8±0.9b	2.5±0.4a	3.2±0.8ab	55	0.7±0.3a	3.0±1.0ab	4.4±1.2b	42
16.4±1.3b	2.1±0.4a	1.8±0.5a	78	23.8±3.9b	2.1±0.4a	2.5±0.6a	73

\+ Calculated as: (Total utilization ÷ Total available)x 100.

* $gm/2m^2$ ± 1 SEm.

a-c Means in row, at each time, followed with the same letter do not differ significantly ($P > 0.05$).

Furthermore, bluebunch wheatgrass production in the big sagebrush community was less in the burned areas than in the clipped.

Deer and cattle selected a greater proportion of bluebunch wheatgrass than of any other species (Tables 18, 19, 20, 21). Deer also selected a large proportion of Sandberg's bluegrass as well as a variety of forbs. As bluebunch wheatgrass selection declined from observation 1 to 3, Sandberg's bluegrass selection increased. Selection of forbs by deer appeared to decline in the big sagebrush community and to increase in the Douglas fir community from observation 1 to 3. There was no evidence to indicate that selection of forages, other than bluebunch wheatgrass, differed among the burned, clipped and control plots.

The only non-grasss forage selected in major proportions by cattle was crazyweed (Oxytropis campestris) in the Douglas fir community. This forb was available only on that range and was readily selected from each treatment (Table 21).

Individuals of both deer and cattle selected bluebunch wheatgrass among treatments in a similar manner during the first observation (Table 22). Generally, the number of bites taken from each treatment increased from the control to the clipped to the burned. Differences between the latter were often not significant ($P>0.05$).

Selection of bluebunch wheatgrass, determined by indirect measurements on the plant, closely reflected

Table 18. Forage selection by deer in relation to treatment and average grazing intensity in the *Artemisia tridentata* community during April, 1976 (n=12).

	OBSERVATION PERIOD								
	First			Second			Third		
	Control	Clip	Burn	Control	Clip	Burn	Control	Clip	Burn
				Mid-April					
Plant type									
Grasses[1]	8*	28	55	11	33	46	35	27	27
Forbs[2]	5	1	1	2	1	3	tr.**	1	0
Shrubs[3]	0	1	tr.	2	1	tr.	6	2	1
All Forages	13	30	57	15	35	50	42	30	28
Species									
Agropyron spicatum	4	22	48	5	22	34	21	16	15
Poa sandbergii	4	6	9	6	11	12	11	11	12
Total bites/obs. period		1290			1088			2484	
Grazing intensity[4]		19			33			44	
				Late April					
Plant type									
Grasses[1]	6	29	51	28	19	44	21	38	32
Forbs[2]	6	2	6	1	2	3	4	1	1
Shrubs[3]	tr.	0	0	2	tr.	tr.	2	tr.	0
All Forages	12	31	57	31	21	48	27	40	33
Species									
Agropyron spicatum	3	24	42	18	15	32	13	29	27
Poa sandbergii	2	3	5	2	2	6	3	8	4
Total bites/obs. period		1530			1281			1079	
Grazing intensity[4]		11			38			55	

1 Includes *Agropyron spicatum*, *Bromus tectorum*, *Stipa comata*.
2 Includes *Antennaria* sp., *Calochortus macrocarpus*, *Erigeron* sp., *Lithospermum ruderale*, *Lommatium macrocarpum*, *Ranunculus* sp.
3 Includes *Artemisia frigida*, *Artemisia tridentata*.
4 Calculated as: (total utilized ÷ total available)x 100.
* Percent of total bites per observation period.
** Less than .5%.

Table 19. Forage selection by deer in relation to treatment and to average grazing intensity in the *Pseudotsuga menziesii* community during April, 1976 (n=12).

	OBSERVATION PERIOD					
	First			Second		
	Control	Clip	Burn	Control	Clip	Burn
Mid-April						
Plant type						
Grasses[1]	5*	34	57	28	45	23
Forbs[2]	2	1	1	1	1	1
Shrubs[3]	0	0	0	tr.**	1	tr.
All Forages	7	35	58	29	47	24
Species						
Agropyron spicatum	4	32	55	24	42	20
Poa sandbergii	1	1	2	0	1	2
Total bites/obs. period		1589			1602	
Grazing intensity[4]		20			39	
Late April						
Plant type						
Grasses[1]	9	30	48	15	27	41
Forbs[2]	3	7	3	6	4	6
Shrubs[3]	0	0	tr.	tr.	0	0
All Forages	12	37	51	21	32	47
Species						
Agropyron spicatum	8	26	45	11	22	33
Poa sandbergii	tr.	4	3	2	4	6
Total bites/obs. period		2515			1900	
Grazing intensity[4]		15			27	

1 Includes *Agropyron spicatum*, *Koeleria cristata*, *Poa sandbergii*, *Stipa comata*.
2 Includes *Achillea millefolium*, *Allium cernum*, *Antennaria* sp., *Artemisia caudata*, *Aster* sp., *Calochortus macrocarpus*, *Lommatium macrocarpum*, *Oxytropis campestris*, *Tragopogon pratensis*.
3 Includes *Artemisia frigida*, *Artemisia tridentata*, *Chrysothamnus nauseosus*.
4 Calculated as: (total utilized ÷ total available)x 100.
* Percent of total bites per observation period.
** Less than .5%.

Table 20. Forage selection by cattle in relation to treatment and to average grazing intensity in the Artemisia tridentata community during May, 1976.

	OBSERVATION PERIOD								
	First			Second			Third		
	Control	Clip	Burn	Control	Clip	Burn	Control	Clip	Burn
Early May									
Plant type									
Grasses[1]	2*	41	57	14	38	47	18	46	36
Forbs and Shrubs[2]	0	0	0	0	0	tr.**	0	0	0
All Forages	2	41	57	14	38	48	18	46	36
Species									
Agropyron spicatum	2	41	57	14	38	47	18	46	36
Total bites/obs. period		1396			442			164	
Grazing intensity[3]		21			31			55	
Late May									
Plant type									
Grasses[1]	3	42	55	22	47	31	38	32	29
Forbs and Shrubs[2]	0	tr.	tr.	0	0	0	tr.	tr.	1
All Forages	3	42	55	22	47	31	38	32	30
Species									
Agropyron spicatum	3	41	52	22	47	31	36	28	28
Total bites/obs. period		2802			170			2136	
Grazing intensity[3]		27			41			73	

1 Includes Agropyron spicatum, Bromus tectorum, Sporobolus cryptandrus, Stipa comata.
2 Includes Calochortus macrocarpus, Erigeron sp., Lommatium macrocarpum, Oxytropis campestris, Artemisia tridentata, Chrysothamnus nauseousus.
3 Calculated as: (total utilized ÷ total available)x 100.
* Percent of total bites per observation period.
** Less than .5%.

Table 21. Forage selection by cattle in relation to average grazing intensity in the *Pseudotsuga menziesii* community during May, 1976.

	OBSERVATION PERIOD								
	First			Second			Third		
	Control	Clip	Burn	Control	Clip	Burn	Control	Clip	Burn
					Early May				
Plant type									
Grasses[1]	2*	52	44	56	20	18	53	22	20
Forbs[2]	1	1	tr.**	2	3	1	3	1	1
All Forages	3	53	44	58	23	19	56	23	21
Species									
Agropyron spicatum	2	51	44	53	19	16	51	21	20
Koeleria cristata	0	1	tr.	3	1	2	2	1	tr.
Oxytropis campestris	1	1	tr.	1	3	tr.	1	1	tr.
Total bites/obs. period		4148			1132			1159	
Grazing intensity[3]		43			55			78	
					Late May				
Plant type									
Grasses[1]	4	36	33	17	33	30	27	29	32
Forbs[2]	9	13	5	8	7	5	5	3	4
All Forages	13	49	38	25	40	35	32	32	36
Species									
Agropyron spicatum	3	33	32	11	29	27	18	24	26
Koeleria cristata	1	3	1	6	5	2	9	5	6
Oxytropis campestris	8	11	4	6	6	4	4	1	2
Total bites/obs. period		4230			902			1048	
Grazing intensity[3]		33			42			73	

1 Includes *Agropyron spicatum*, *Aristida longiseta*, *Carex* sp., *Koeleria cristata*, *Stipa comata*.
2 Includes *Achillea millefolium*, *Anemone* sp., *Artemisia caudata*, *Aster* sp., *Gailardia aristata*, *Gailium boreale*, *Helianthus annuus*, *Linum lewisii*, *Lithospermum ruderale*, *Lomatium macrocarpum*, *Penstemon* sp., *Sisymbrium altissimum*, *Taraxacum officinale*, *Tragopogon pratensis*.
3 Calculated as: (total utilized ÷ total available)x 100.
* Percent of total bites per observation period.
** Less than .5%.

Table 22. Selection of bluebunch wheatgrass by individual animals among treatments in the first observation period (n=12).

Trial			Animal								
Animal species	Community	Time	One			Two			Three		
			Control	Clip	Burn	Control	Clip	Burn	Control	Clip	Burn
Deer	At	Mid-April	0.5^{a} *	9.6^{a}	19.4^{b}	1.2^{a}	3.7^{a}	16.9^{b}	2.6^{a}	10.4^{a}	13.8^{a}
		Late April	0.7^{a}	9.6^{ab}	15.4^{b}	0.6^{a}	9.8^{a}	21.2^{a}	3.0^{a}	10.8^{ab}	16.3^{b}
	Ps	Mid-April	2.5^{a}	11.9^{a}	11.2^{a}	0.8^{a}	11.3^{a}	42.0^{b}	2.3^{a}	19.7^{a}	19.2^{a}
		Late April	1.7^{a}	19.5^{b}	27.1^{b}	7.8^{a}	14.2^{a}	41.2^{b}	6.6^{a}	16.6^{b}	25.6^{c}
Cattle	At	Early May	1.8^{a}	30.3^{b}	37.3^{b}	0^{a}	12.2^{b}	13.2^{b}	0.2^{a}	4.9^{b}	16.4^{c}
		Late May	0.4^{a}	34.8^{b}	39.2^{b}	3.5^{a}	39.9^{b}	48.4^{b}	2.8^{a}	21.2^{b}	34.8^{b}
	Ps	Early May	4.2^{a}	59.5^{b}	44.2^{b}	0.7^{a}	66.6^{b}	53.5^{b}	1.8^{a}	49.5^{b}	53.5^{b}
		Late May	0.4^{a}	39.7^{b}	35.3^{b}	4.2^{a}	40.5^{b}	46.2^{b}	4.9^{a}	36.2^{b}	30.2^{b}

* bites per plot

a–c Means with same letter within subset do not differ significantly ($P > 0.05$).

At <u>Artemisia tridentata</u>; Ps <u>Pseudotsuga menziesii</u>.

selection based on bite counts. As grazing intensity increased, selection differences among treatments decreased (Fig. 7 and 8) and, for cattle, reversed in order of magnitude (Fig. 8). Deer were extremely reluctant to switch from a preferred forage to one less preferred (Fig. 7). Utilization was about twice as high on bluebunch wheatgrass from the burned treatment than from the clipped treatment yet the proportion selected was similar. Deer switched from grazing the clipped plants to the control plants in late April at 55% grazing intensity. At this point the degree of bluebunch wheatgrass utilization on the clipped and control plants was 60 and 30% respectively.

Cattle selected similar proportions of bluebunch wheatgrass from the clipped and burned treatments at all levels of grazing intensity (Fig. 8). Switching from the treated to control plants occurred between 40 and 55% grazing intensity. This point occurred, in the big sagebrush community, when clipped and burned plants were utilized 55 and 75% respectively and, in the Douglas fir community, when clipped and burned plants were utilized 70 and 80% respectively.

Deer showed greatest relative preference for bluebunch wheatgrass from the burned treatment at all levels of grazing intensity (Fig. 7). Relative preference for the control increased gradually with increased utilization. Cattle responded in a similar manner as deer but with variation (Fig. 8). Cattle showed less contrast in their

Figure 7. First year effect of fall treatment (control,——; clip,------; burn,—·—) on the utilization, selection and relative preference of bluebunch wheatgrass by deer, relative to total utilization from all treatments in two communities during May, 1976. Utilization differences between treatments that have different letters are significant ($P < 0.05$).

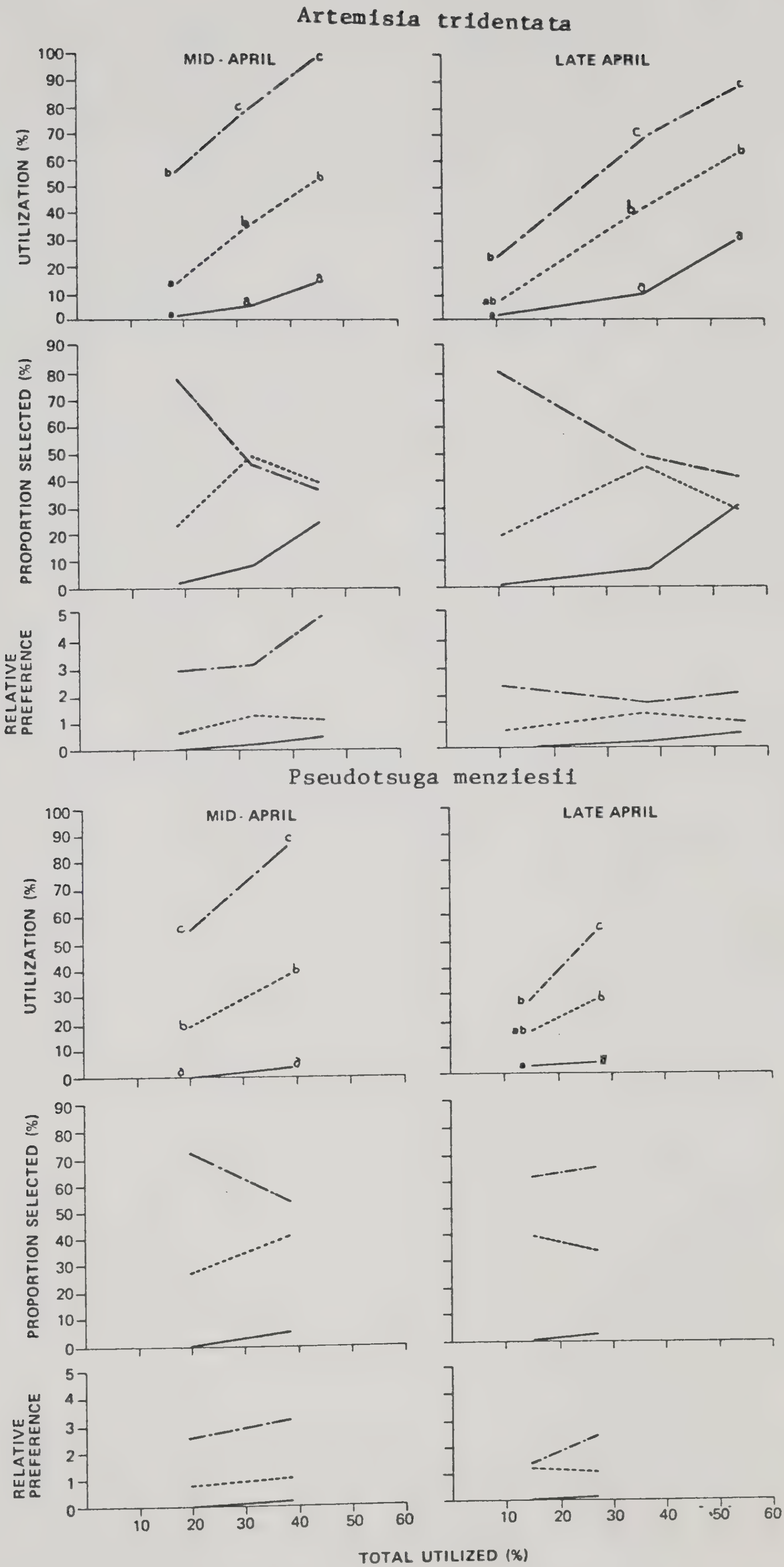
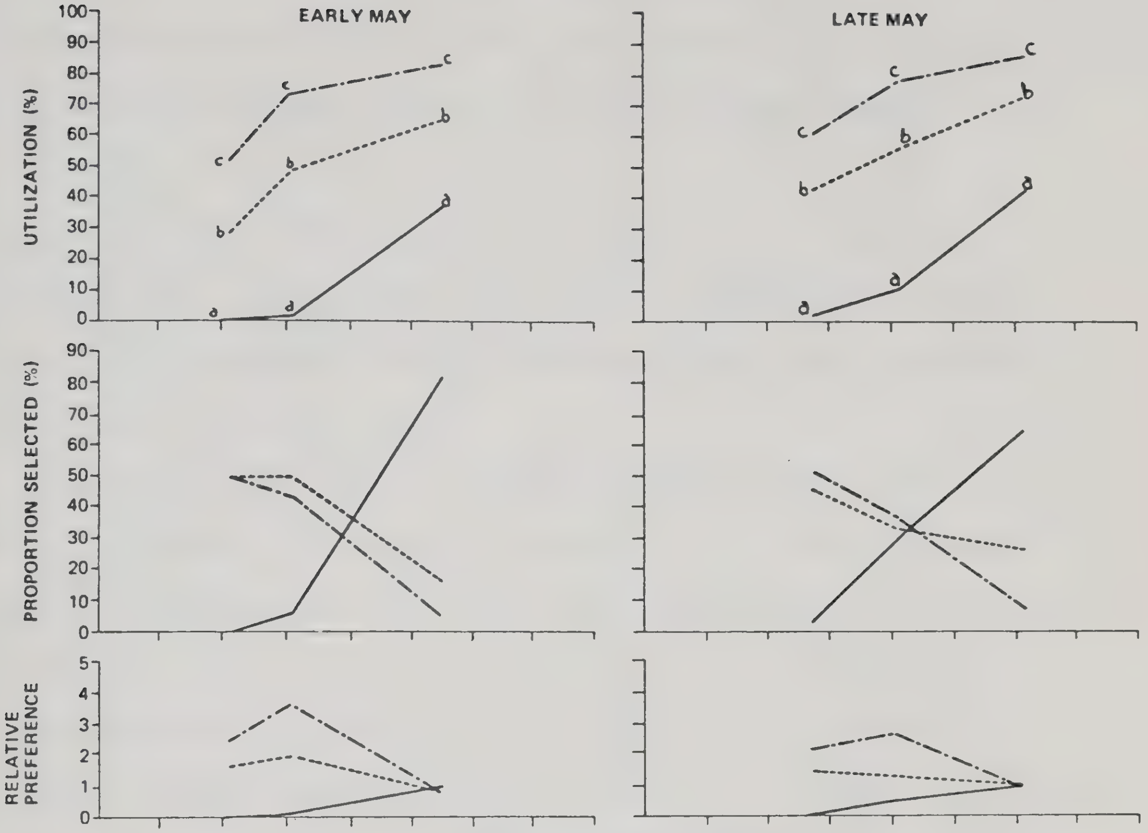
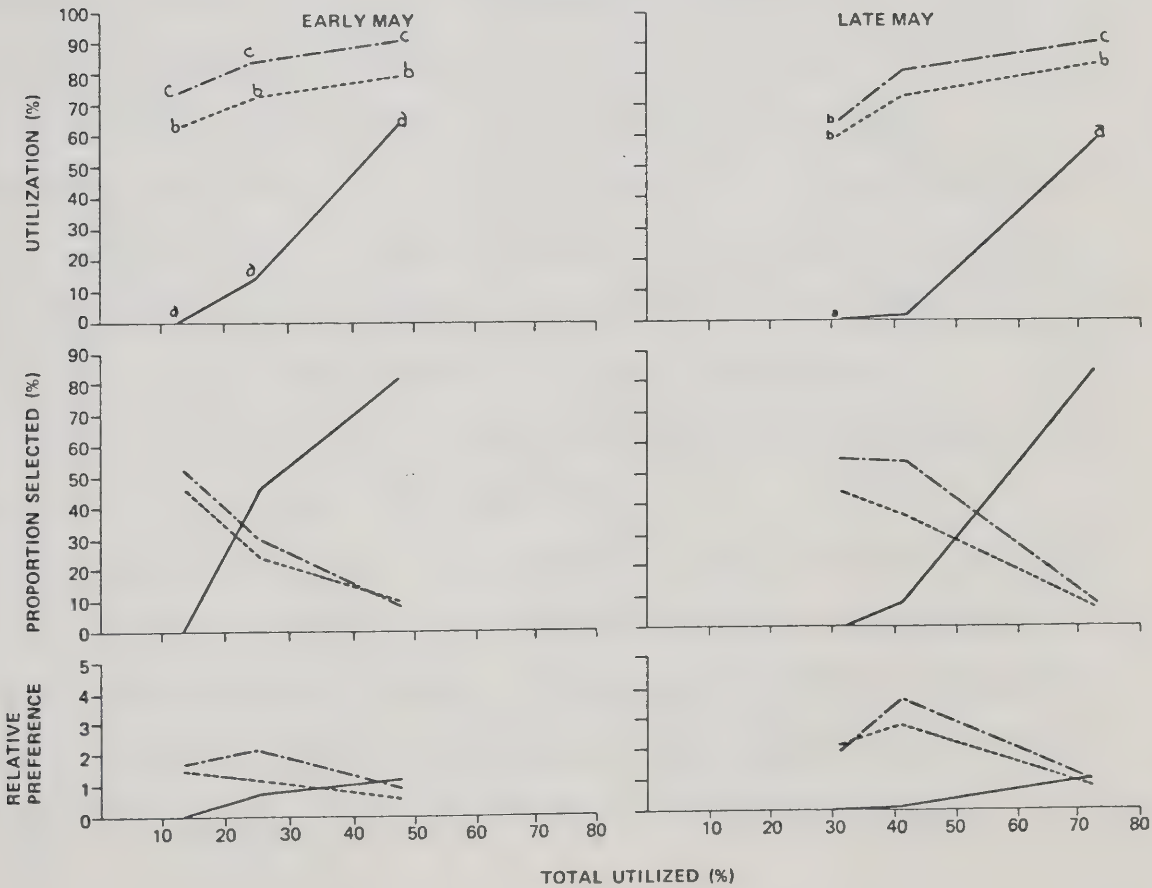

Artemisia tridentata
MID - APRIL
LATE APRIL
UTILIZATION (%)
PROPORTION SELECTED (%)
RELATIVE PREFERENCE
Pseudotsuga menziesii
MID- APRIL
LATE APRIL
UTILIZATION (%)
PROPORTION SELECTED (%)
RELATIVE PREFERENCE
TOTAL UTILIZED (%)

Figure 8. First year effect of fall treatment (control,——; clip,-----; burn,–·–·) on the utilization, selection and relative preference of bluebunch wheatgrass by cattle, relative to total utilization from all treatments, in two communities during May, 1976. Utilization differences between treatments that have different letters are significant ($P < 0.05$).

Artemisia tridentata



Pseudotsuga menziesii



relative preferences for clipped and burned plants; control plants were preferred relatively more as other forage disappeared.

The average time per bite of forage was, generally, highest in the control and least in the burned area (Tables 23 and 24). This relationship did not appear to be affected by the level of utilization.

The weight per bite of bluebunch wheatgrass was affected by both treatment and level of utilization (Tables 23 and 24). The weight per bite from the control was insignificant relative to the weight per bite from the clipped and burned treatments. For deer, this ratio was approximately 1:6 for the clipped treatment and 1:12 for the burned treatment. The ratio between the clipped and burned treatments was approximately 1:2. For cattle the weight per bite ratio from the control to the clipped and burned treatments was about 1:5 in two trials, 1:4 in one trial and 1:1 in another. The weight per bite relationship between the clipped and burned treatments was not consistent among cattle trials. On the contrary, a bite from clipped treatment was larger in the big sagebrush community and smaller in the Douglas fir community.

In the deer trials, the weight per bite relative to one another tended to equalize as grazing intensity increased. In the cattle trials, however, a reverse situation developed where a bite from the control plants was from 2 to 10 times heavier than a bite from the clipped and burned plants.

Table 23. Effect of fall clipping or burning on the foraging behavior of deer in relation to average grazing intensity (from the first to last observation period) in two communities during April, 1976.

Treatment	OBSERVATION PERIOD 1 Sec. per bite†	OBSERVATION PERIOD 1 Gms. per bite*	OBSERVATION PERIOD 1 Wt.* relative to control	OBSERVATION PERIOD 2 Sec. per bite	OBSERVATION PERIOD 2 Wt. relative to control	OBSERVATION PERIOD 3 Sec. per bite	OBSERVATION PERIOD 3 Wt. relative to control
Artemisia tridentata Mid-April							
Control	1.73	.029	1.0	2.10	1.0	1.83	1.0
Clip	1.61	.189	6.5	1.93	1.4	2.09	2.1
Burn	1.65	.305	10.5	2.14	.8	1.72	2.2
Bites per minute of observation		13.0		11.3		8.3	
Artemisia tridentata Late April							
Control	2.93	.015	1.0	3.09	1.0	2.68	1.0
Clip	3.39	.093	6.3	2.08	7.8	2.35	.44
Burn	2.85	.218	14.8	2.62	4.1	2.14	.64
Bites per minute of observation		12.4		6.0		10.3	
Pseudotsuga menziesii Mid-April							
Control	2.33	.011	1.0	2.28	1.0		
Clip	1.89	.047	4.2	1.76	4.2		
Burn	1.59	.072	6.4	1.99	11.5		
Bites per minute of observation		11.6		10.5			
Pseudotsuga menziesii Late April							
Control	1.98	.004	1.0	2.71	1.0		
Clip	1.61	.072	18.6	2.03	7.6		
Burn	1.87	.065	16.8	2.14	9.2		
Bites per minute of observation		10.7		11.3			

† Bites average for all forages.

* Weight per bite of bluebunch wheatgrass.

Table 24. Effect of fall clipping or burning on the foraging behavior of cattle in relation to average grazing intensity (in observation period 1 through 3) in two communities during May, 1976.

Treatment	OBSERVATION PERIOD 1 Sec. per bite†	OBSERVATION PERIOD 1 Gms. per bite*	OBSERVATION PERIOD 1 Wt.* relative to control	OBSERVATION PERIOD 2 Sec. per bite	OBSERVATION PERIOD 2 Wt. relative to control	OBSERVATION PERIOD 3 Sec. per bite	OBSERVATION PERIOD 3 Wt. relative to control
			Artemisia tridentata Early May				
Control	1.79	.06	1.0	2.76	1.0	1.52	1.0
Clip	1.76	3.90	63.9	2.22	2.8	2.58	0.1
Burn	1.93	2.76	44.6	2.02	2.4	2.88	0.04
Bites per minute of observation		10.8		2.4		1.5	
			Artemisia tridentata Late May				
Control	2.13	3.00	1.0	2.92	1.0	2.35	1.0
Clip	1.73	3.22	1.1	2.30	.5	2.39	0.5
Burn	1.65	2.83	.9	2.13	.9	2.35	0.2
Bites per minute of observation		23.4		3.8		7.9	
			Pseudotsuga menziesii Early May				
Control	2.19	.38	1.0	2.79	1.0	2.43	1.0
Clip	1.34	1.29	3.4	2.13	1.5	1.75	0.3
Burn	1.47	1.71	4.6	1.81	2.2	1.77	0.3
Bites per minute of observation		34.6		6.9		4.4	
			Pseudotsuga menziesii Late May				
Control	1.91	.03	1.0	2.63	1.0	2.59	1.0
Clip	1.58	1.41	54.2	1.78	1.7	1.96	0.07
Burn	1.72	1.85	71.0	2.03	2.6	1.94	0.07
Bites per minute of observation		26.6		10.0		23.3	

† Bites average for all forages.

* Weight per bite of bluebunch wheatgrass.

Foliage height of bluebunch wheatgrass was similar among treatments in April, however, differences became apparent in May (Table 25). In the big sagebrush community, foliage of burned plants was shorter than foliage of clipped or control plants. In the Douglas fir community, plants of both clipped and burned treatments were shorter than foliage of control plants.

Average stubble heights (±1 SEm), for plants of the clipped plots were: for the deer trials in the big sagebrush community, 6.2±.4 and 5.5±.1 for mid-April and late April respectively; in the Douglas fir community, 7.1±.4 and 4.7±.2 for mid-April and late April respectively; and for the cattle trials in both the big sagebrush and Douglas fir communities, 4.8±.3 and 6.2±.3 respectively. The values above 6 cm were significantly ($P<0.05$) greater than those less than 5 cm. Burning reduced the stubble to an average of 3.0 cm in the big sagebrush community and to 1.8 cm in the Douglas fir community.

5.2.2 Second Year after Treatment

Dry matter estimates of available weathered forage (post-grazing regrowth) and spring production are given in table 26. Estimates of weathered forage varied considerably among trials and treatments. In the big sagebrush community, weathered forage was most abundant in the control plots of the deer trials and in the burned plots of the cattle trials. However, in the Douglas fir community, yields tended

Table 25. Height (cm, ±1 SEm) of bluebunch wheatgrass plants (less inflorescence) in deer trials during April and in cattle trials during May, 1976.

Control	Clip	Burn	Control	Clip	Burn
Mid-April			*Late April*		
Artemisia tridentata (n=43 to 78)					
11.2 0.4[a]	12.7±0.3[b]	11.0±0.4[a]	16.6±0.9[b]	17.0±0.8[b]	14.6±0.7[a]
Pseudotsuga menziesii (n=61 to 78)					
11.6 0.3[b]	10.7±0.3[a]	11.6±0.3[b]	15.1±0.4[b]	11.6±0.4[a]	12.2±0.3[a]
Early May			*Late May*		
Artemisia tridentata (n=84 to 157)					
27.8±0.6[b]	27.1±0.6[b]	18.2±0.4[a]	37.5±0.3[c]	34.1±0.7[b]	28.7±0.6[a]
Pseudotsuga menziesii (n=103 to 186)					
29.2±0.8[b]	22.0±0.4[a]	22.6±0.4[a]	31.2±1.1[b]	27.4±0.7[a]	26.9±0.7[a]

a–c Means with same letter within subset do not differ significantly ($P > 0.05$).

Table 26. Regrowth and production of bluebunch wheatgrass in two communities during April and May the second spring after treatment (1977). Grazing by deer and cattle was imposed in the first spring (1976) (n=22 to 28).

Animal Species	Grazing Date	First spring post-grazing regrowth† Control	Clip	Burn	Harvest Date	Second spring treatment Control	Clip	Burn
				Artemisia tridentata				
Deer	Mid-April, 1976	$62.4 \pm 6.1^{*a}$	27.4 ± 2.9^{a}	34.3 ± 3.5^{a}	Early April, 1977	4.9 ± 0.6^{a}	5.3 ± 0.6^{a}	7.1 ± 0.9^{a}
Cattle	Early May, 1976	37.9 ± 4.8^{a}	30.1 ± 4.2^{a}	57.6 ± 7.4^{b}	Mid-May, 1977	36.0 ± 4.8^{a}	35.0 ± 4.9^{a}	44.6 ± 4.8^{a}
Cattle	Late May, 1976	34.0 ± 6.9^{a}	25.7 ± 4.6^{a}	65.2 ± 7.7^{b}	Mid-May, 1977	32.9 ± 7.1^{a}	29.3 ± 5.5^{a}	47.2 ± 6.8^{a}
				Pseudotsuga menziesii				
Cattle	Early May, 1976	36.4 ± 5.1^{a}	25.0 ± 3.6^{a}	25.3 ± 2.5^{a}	Late May, 1977	21.6 ± 3.9^{b}	13.6 ± 1.7^{a}	15.1 ± 1.6^{a}
Cattle	Late May, 1976	34.3 ± 3.6^{b}	16.3 ± 3.0^{a}	15.6 ± 1.8^{a}	Late May, 1977	21.4 ± 2.7^{b}	9.9 ± 1.6^{a}	12.1 ± 1.6^{a}

a&b Means with same letter, in row of subset, do not differ significantly ($P > 0.05$).
\+ Measured as weathered forage the next spring.
* $gm/m^2 \pm 1SEm$.

to be greater in the control plots.

Available weathered forage was similar among treatments between the two cattle trials in the big sagebrush community. In the Douglas fir community, however, the burned and clipped plots of the trial grazed in late May had about 35% less weathered forage than their counterparts of the trial grazed in early May. This trial x treatment interaction also existed, but to a lesser degree, with spring production.

Although estimates of spring forage production did not differ significantly ($P<0.05$) among treatments in the big sagebrush community, there was a consistent trend for greater production in the burned plots. However, in the Douglas fir community, the control plots yielded significantly ($P<0.05$) more forage than plots of the other treatments.

Deer selected a greater proportion of spring production from burned plots regardless of grazing intensity (Fig. 9). Bluebunch wheatgrass from control plants was used least over the entire period. Selection among treatments increased from the control to the burned treatment. Relative preference for bluebunch wheatgrass followed the same order. Relative preference for forage from the control was about one-half that for forage from burned plots.

Cattle selected forage in a similar manner as deer but with less contrast among treatments (Fig. 10 and 11). The two cattle trials in the big sagebrush community represented

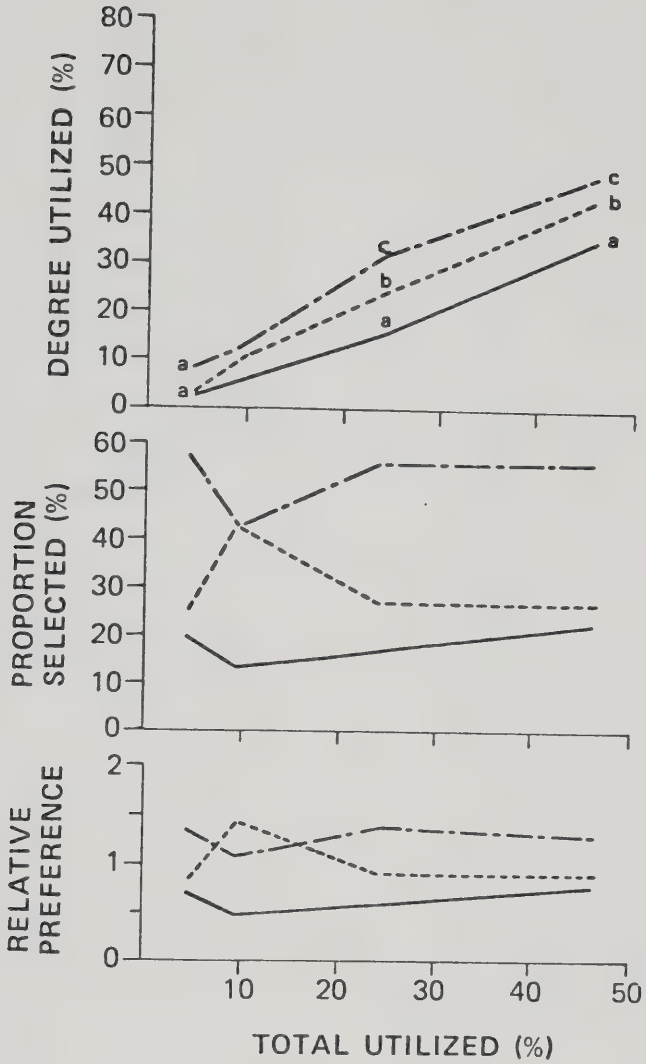


Figure 9. Second year effect of fall treatment (control,——; clip,-----; burn,—·—) on the utilization, selection and relative preference of bluebunch wheatgrass by deer, relative to total utilization from all treatments, in the _Artemisia tridentata_ community during April, 1977. Grazing was imposed the first spring after treatment. Utilization differences between treatments that have different letters are significant ($P < 0.05$).

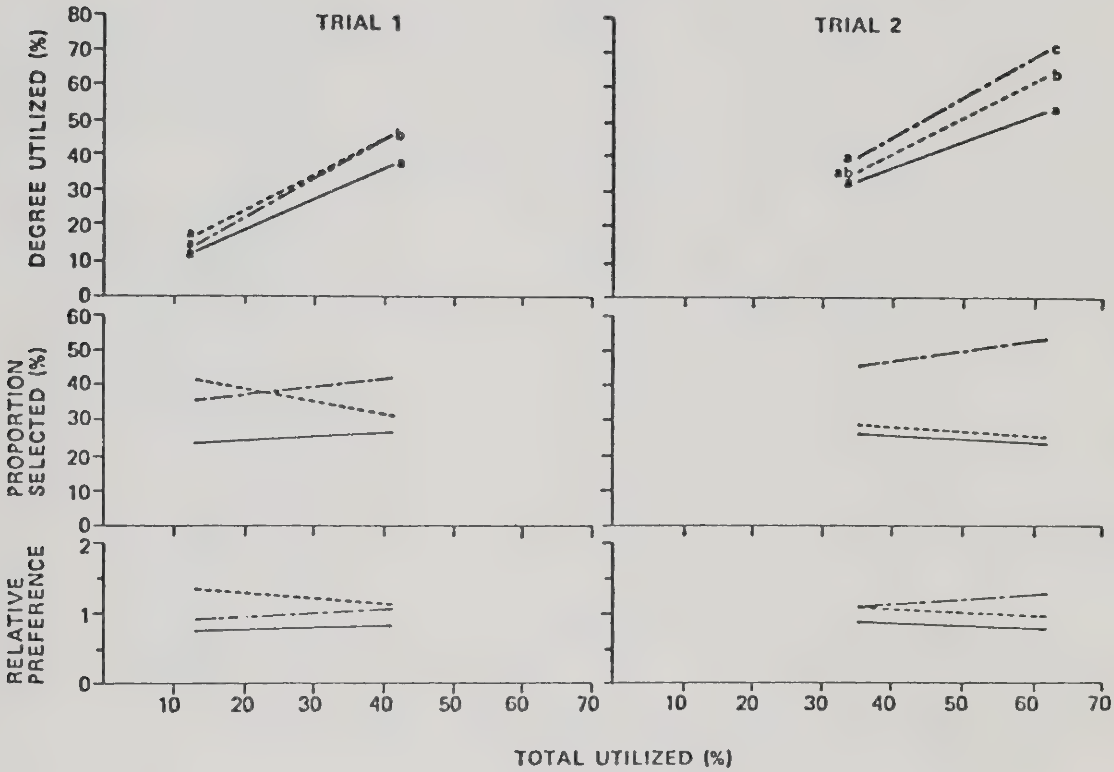


Figure 10. Second year effect of fall treatment (control,——; clip,-----; burn,-·-·-) on the utilization, selection and relative preference of bluebunch wheatgrass by cattle, relative to total utilization from all treatments, in the <u>Artemisia tridentata</u> community during May, 1977. Grazing was imposed the first spring after treatment. Utilization differences between treatments that have different letters are significant ($P < 0.05$).

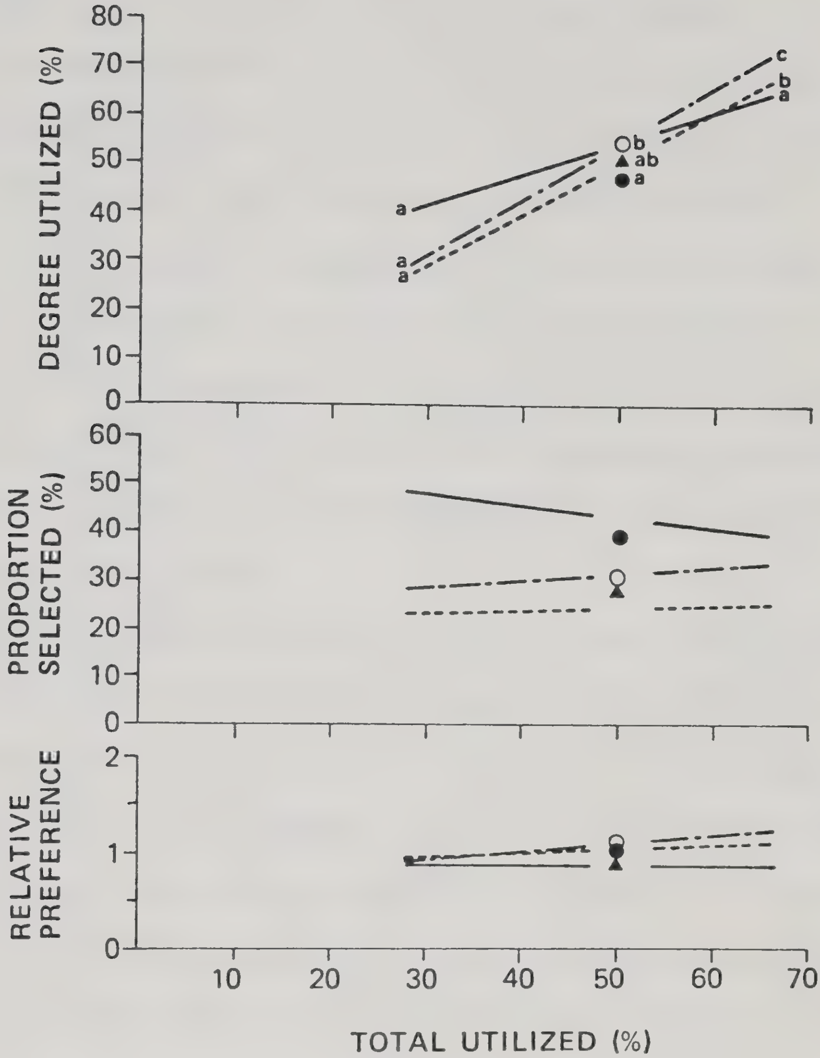


Figure 11. Second year effects of fall treatment (control,—— or ● ; clip,------ or ▲ ; burn,—·— or ○) on the utilization, selection and relative preference of bluebunch wheatgrass by cattle, relative to total utilization from all treatments, in the Pseudotsuga menziesii community during May, 1977. Information from two trials are identified by lines and symbols. Grazing was imposed the first year after treatment. Utilization differences between treatments that have different letters are significant ($P < 0.05$).

different levels of grazing intensity (Fig. 10) but selection among treatments was similar. Forage from the control plots was selected least at all levels of grazing intensity. Forage from the burned plots was generally selected in the greatest proportion. Relative preference of forage from the burned and clipped plots were similar. However, the clipped treatment was preferred at low levels of grazing intensity (Trial 1) and the burned treatment at high levels of grazing intensity (Trial 2). The control was preferred least throughout.

Information from two cattle trials in the Douglas fir community complement one another (Fig. 11). In both trials, forage from control plots was selected most while forage from clipped plots was selected least. However, forage in burned plots was utilized to a greater degree than that of other treatments. Relative preferences among treatments were comparable, but the magnitude of difference was less than in the big sagebrush community (Fig. 11).

The relationship between the utilization estimates of spring production (X) and weathered forage (Y) was linear, with a regression coefficient of nearly 1. The equations for this relationship, and their r^2, were (a) in the big sagebrush community: $Y=4.4 + 0.94X$, $r^2=.89$; (b) and, in the Douglas fir community: $Y=-3.3 + .99X$, $r^2=.86$.

5.3 Discussion

5.3.1 The Effect of Fall Clipping or Burning on Forage Selection

Westoby (1974) and Ellis *et al.* suggest that the forage selection strategy of herbivores can be to optimize nutritional balance. This strategy describes, in part, the observations made on forage selection by deer and cattle.

In the early stages of each trial, deer and cattle optimized both energy and nutrients by avoiding litter and by selecting burned plants in preference to clipped and control plants. The nutrient and energy status of litter is low. Standing litter may have 0.3% nitrogen, 80% NDF and 55% ADF (Unpublished data). This compares with, approximately, 3% nitrogen, 60% NDF and 35% ADF in young forage. On this basis, the predicted digestible energy content (Kcal/gm) for litter is 1.84 and for young forage, 3.23 (Waldern 1972). On the other hand, voluntary intake (gm/kg body weight$^{.75}$) is 45 for litter and 63 for young forage (van Soest 1965). These values, derived for sheep and cattle, indicate that voluntary intake of digestible energy (Kcal/kg body weight$^{.75}$) would be 83 for litter and 203 for young forage. Nitrogen intake (gm/kg body weight$^{.75}$) would be .14 and 1.9 respectively for the same forages. The energy and nitrogen requirements for maintenance in sheep (N.R.C. 1975) and in cattle (N.R.C. 1970) are adequately met by young forage but considerably deficient in litter.

Earlier discussion (Chapter 3) indicated that predicted

dry matter, mineral and digestible energy intake in May was greatest for burned plants. Nutritional balance would, therefore, appear to be optimized by cattle selecting those plants in prefernce to forage from other treatments. Although deer displayed similar preferences, nutrient differences were less pronounced and predicted energy not consistently different among treatments in April (Table 10). This indicates that other strategies also play a role in forage selection.

Evidence for another strategy, to minimize time of forage intake, comes from the relative dry matter capture rates (calculated as the weight per bite relative to the control, divided by seconds per bite; from information in tables 23 and 24). This assumes that the time required to take a bite of bluebunch wheatgrass from each treatment was proportionate to the time required per bite for both green forage and standing litter from that treatment. Consumption of standing litter may be predicted from observations made in the field by the author. Although deer may have ingested litter, that proportion would be minor. Deer were observed to select new growth from among standing litter. Cattle, on the other hand, appeared to utilize standing litter in proportion to new growth. Since the proportion of new growth to standing litter was about 1:1 in the big sagebrush community and 1:3 in the Douglas fir community, an estimate of utilization may be obtained by using the appropriate multiplier.

Generally, for both deer and cattle, the relative capture rate during the first period of observation was greater in the treated areas than in the control. This could not, however, account for the disparity in utilization between them. For example, in the deer trials the relative capture rate ratio of the control to burn averaged 1:14 while the utilization ratio of the control to burn averaged 1:44. The corresponding ratios for cattle, adjusted for mature forage in the control, were 1:15 and 1:100 respectively.

As grazing intensity increased, the treatment ratios for relative capture rate and utilization tended to reverse from those above. Where a third observation for deer was obtained, the ratios had declined to 1:1.5 and 1:1.4 for capture rate and utilization respectively. The corresponding ratios for the third observation in the cattle trials were 39:1 and 28:1. The ratio similarity demonstrates potential effect of capture rate on utilization; indicating greater importance of the time minimization strategy of selection as food became less available.

Selection among treatments, in the second year after treatment (Figures 9 to 11) was similar as in the first year (Figures 7 and 8). The most obvious difference from the first was a decline in selectivity. This was particularly noticeable with cattle who demonstrated little or no preference for forage from either the clipped or burned plots.

Two factors thought to affect selection in the first year after treatment were the presence or absence of mature forage and differences in plant chemistry. In the second year mature forage was present in all plants. In fact, tiller density was greater in plants on the burned plots and less in plants of the control (Chapter 3). Therefore, an hypothesis of forage selection based solely on the barrier effect of mature forage would be rejected by evidence from this study. Apparently plant chemistry was important in influencing selection although deer displayed reluctance to select forage from among weathered stalks where their density was high.

5.3.2 Comparison of Deer and Cattle Forage Selection

The above discussion was general to both deer and cattle. Selection differences between the two were evident and may be explained on a tactical basis. A variety of tactics have been hypothesized (Ellis *et al*. 1976). In general they pertain to nutritive requirement and foraging efficiency. To contrast between deer and cattle, perhaps the most important differences influencing selection tactics are their metabolic weight, rumen to metabolic weight ratio and morphological differences of the mouth. The first influences nutrient requirement, the second the ability to ingest sufficient nutrients and the third, the ability to select sufficient quality to meet their nutritional requirements. For example the metabolic weight ($W^{.75}$/kg) of a 540 kg cow

and 70 kg deer is 112 kg and 24 kg respectively. This indicates that deer require 1.6 times more energy per kg live weight than does the cow. Furthermore, the rumino-reticular volume (l) in proportion to live weight (kg) is about 10% for deer and 45% for cattle. This demonstrates considerably less ability by deer to retain forage and contributes to a less efficient digestive system. These handicaps are offset, in part, by morphological differences of the mouth permitting antelope and, presumably, deer to select a higher quality forage than cattle (Ellis and Travis 1975).

Although the feeding behaviors of deer and cattle were not studied concurrently, several comparisons can be made. Deer selected a greater proportion of forbs despite their availability being less in April than in May. Deer also selected more Sandberg's bluegrass. This forage was probably most nutritious in April prior to cattle use. In addition, the short leaves of Sandberg's bluegrass limits utilization by cattle.

5.3.3 Comparative Response Among Trials

The observations among trials for each species were in close agreement with one another. Several noteworthy exceptions were evident. Among the deer trials the burned treatment, compared to the clipped, was preferred relatively more in the big sagebrush community than in the Douglas fir community. This indicates an interaction of the environment

with factors determining preference or a response to the relatively low biomass present in the Douglas fir community (Table 21). The latter effect would be to reduce selectivity by increasing the search effort and reducing the profit associated with the animals' choice. In fact, the estimated weight per bite from the burned treatment in the big sagebrush community was 1.9 times greater than a bite from the clipped plot (Table 23). In the Douglas fir community the difference was by a factor of only 1.2.

Deer and cattle both took more forage per bite in the big sagebrush community than in the Douglas fir community. This effect was likely the result of lower forage availability in the Douglas fir community (Tables 21 and 22) and shorter tiller lengths. Allden and Whitaker (1970) found that, sheep increase their bite size almost linearly with increaing tiller lengths.

The uncharacteristically heavy bite estimate by cattle from control plants in late May, in the big sagebrush community (Table 24), may be explained on the basis of tiller length as well. In that trial tiller lengths were unusually high (Table 25), a about 2 cm below the maximum height of standing litter. This length may be sufficient to negate the barrier effect evident in the early stages of grazing.

5.3.4 Treatment Effects on the Forage

Production estimates of weathered and spring forage were influenced by both fall treatment and subsequent spring grazing. Earlier work (Chapter 3) has shown that tillering in bluebunch wheatgrass was somewhat stimulated by burning while spring grazing stimulated considerably more tiller development. Tan *et al*. (1977) found tiller density to be a major determinant of productivity in smooth brome (*Bromus inermis*). Daubenmire (1968) reported that burning often results in a first year decline in production of grasses but in following years yields may be higher than normal. This implies lighter first-year tillers on burned areas and recovery toward normal weight in the second year.

In the present study, the post-grazing regrowth was represented by weathered forage. The contrast in yields among treatments between the deer and cattle trials, in the big sagebrush community, is difficult to interpret. Although experimental error cannot be ruled out, several explanations may be proposed. One is the time of first grazing following treatment. Grazing by deer occurred in April when the carbohydrate reserves were minimal. McLean[6] reported that the lowest carbohydrate reserves occur when leaf length is about 17 cm. At this time the plant is susceptible to damage by severe defoliation. By May the carbohydrate reserves have been replenished and defoliation is less damaging. The varying response among treatments in April was probably caused by different levels of utilization. The first year

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[6] McLean, A. 1978. Unpublished report.

utilization for the clipped and burned plots was about 60 and 90% respectively while for the control plots it was about 20%. Forage utilization in the clipped and burned plots of the May cattle trials was also severe. Although carbohydrate reserves were not believed limitng, the length of favourable growing season was (van Ryswyk and Broersma[7] 1977). Differential response among treatments was caused by a greater number of tillers on the burned plots. Post-grazing tillering in the first year after treatment showed 50% more tillers in plants of the burned plots than in plants of the clipped plots. The intricate relationships described above require further study.

In the Douglas fir community, the relationships between treatment and yield were similar between the two cattle trials although differences in magnitude occurred. Tillering was less a factor on this range (Chapter 3) and residual leaf area after grazing seemed most important. First year utilization of the control plants was about 20% and for the clipped and burned plants, 60 and 80% respectively. The greater contrast among treatments in the second trial may be influenced by a shorter favourable growing season remaining after grazing.

Spring productivity showed two responses, defined by community, among treatments. Although not significant (P>0.05), there was a trend for production in the big sagebrush community to be greatest in burned plots, perhaps

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[7]van Ryswyk, A. and C. Broersma, 1977. Unpublished data.

the result of increased tillering. Tillering was also enhanced in plants of the Douglas fir community, however not sufficiently to compensate for a lighter tiller. Consequently, yields were less on the burn than on the control areas.

The effect of the grazing x treatment interaction on plant mortality was not investigated. No effect was evident on the basis of plant density among treatments. McLean[8] (1978) reported 23% mortality among bluebunch wheatgrass plants clipped more than once to a height of 5 cm in April and a more severe effect for clippings in May. Evidently, the short interval of the first spring grazing trials simulated a single clip.It is not damaging if subsequent soil moisture is adequate for growth.

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[8]McLean, A. 1978 Unpublished report.

6. FORAGE SELECTION AND DISTRIBUTION OF USE

6.1 Methods

6.1.1 Studies on Confined Animals

Four trials were made; two with deer and two with cattle. One trial was made for each species in the big sagebrush community and one in the Douglas fir community. The trials using deer were made in April (1977) and those with cattle in May (1977). The dates corresponded to the period of normal range use by each herbivore species. Four animals were observed in each trial. The deer were a male and female of both 1 and 2-year age classes. The cattle were yearling heifers.

The design was unbalanced, randomized complete block with 6 plots and 3 rows. One plot was burned, 1 undisturbed (control) and 4 grazed. The treatments were made in the fall. Burning was done in November when the relative humidity averaged 55% and the temperature 5°C. Bluebunch wheatgrass plants were ignited individually with a propane torch. Other flammable material was also ignited. Fall grazing was by cattle made prior to the burn and the control plots were protected by fences.

The area of each deer enclosure was .15 ha and of each cattle enclosure, .67 ha. The deer enclosures were fenced with fish-net to a height averaging 1.7 m according to methods described by Willms *et al.* (1978). The cattle enclosures were fenced with 4 strand barbed wire. The

animals were conditioned in similar habitat for at least 7 days prior to each trial.

Availability and utilization estimates of bluebunch wheatgrass were made indirectly as described in section 1 of this part. The modifications made in the second year after treatment were included in calculations for the present estimates. Basically, the observations were made on the plant. Meter-square sub-plots were systematically placed within each plot, the plants mapped on a grid and their basal areas and heights measured. In addition, the ground cover of each species was estimated in 1% classes to 5% cover, and thereafter in 5% classes.

Four sub-plots were established per plot of the deer trials and 16 per plot of the cattle trials. They were surveyed once each day of the trials. The survey consisted of estimating, for each bluebunch wheatgrass plant, the average stubble height and the proportion of area grazed; and, for each additional species, the proportion of area grazed. The deer trials were surveyed seven and five times in the big sagebrush and Douglas fir communities respectively; the cattle trials were surveyed four and five times in those communities respectively. Trials in the big sagebrush community were made first, followed in seven days by the trials in the Douglas fir community.

6.1.2 Studies on Free-Ranging Animals

Two fields, each with an area of about 150 ha, were available for observation. Both fields had 41% Douglas fir community and 59% big sagebrush community. The proportion of each habitat in the big sagebrush community was 25% steep south-facing slope, 48% knoll, and 27% flat field. The habitats were discrete in space and their juxtaposition, relative to one another, the same in each field. One field was grazed by cattle in the fall with a stocking rate of 3.1 ha per AUM. Habitat utilization by cattle was not observed in the fall but previous work (McLean and Willms 1977) revealed that greatest use occurs in the flat field habitat and the least use normally occurs in the treed habitat.

Two small burns were made in winter (1976-77), one in a fall grazed field (.25 ha) and the other in a fall ungrazed field (.5 ha). Insufficient drying times between periods of rainfall maintained moist fuels and restricted the burns to areas of high grass litter accumulation.

6.1.2.1 Forage Selection by Cattle

Five sites (A-E) were selected accordng to available treatments (Table 27). One hundred or more individual plants of bluebunch wheatgrass were selected at each site and their dimensions recorded. The plants were selected within a linear belt transect, 1 m wide and oriented to sample a representative area of the site. Those plants selected were identified by color code sprayed on the ground at their base. Plants within the transect were ignored if they could

Table 27. Site description for the study of treatment effect on bluebunch wheatgrass utilization by free-ranging cattle.

Site	Habitat description	Proportion: plants grazed†/ plants ungrazed	Stubble height of grazed plants (cm±SEm)	Available spring forage (gm/plant; $\bar{x}$±SEm)		
				Control	Grazed	Burned
A	Big sagebrush-bluebunch wheatgrass (knoll)	1.2:1	7.1±0.4	5.3a±.4	5.7a±.5	
B	Douglas fir-big sagebrush ecotone	4.0:1	7.6±0.5	4.5a±.8	4.3a±.6	
C	Douglas fir-bluebunch wheatgrass (near ecotone)	1.0:1	7.6±0.3	6.2b±.3	3.9a±.2	
D	Douglas fir-bluebunch wheatgrass	0.5:1	5.3±2.9	5.9b±.5	2.2a±.2	6.0b±.4
E	Douglas fir-bluebunch wheatgrass	0.0:1		3.5b±.3		2.5a±.2

† Grazed by cattle in fall.
a-b Averages in row with same letter do not differ significantly ($P < 0.05$).

not be distinguished from one another without labelling or if they were too small (<15 cm circumference). Estimates of utilization were made weekly during the grazing period.

6.1.2.2 Forage Selection by Deer

Treatment selection by free-ranging deer was observed on sites prepared for other studies. The sites for the study of confined cattle (Chapter 6.1.1) provided 2 areas. Both (A in the big sagebrush community and B in the Douglas fir community) had randomized complete block designs and were unbalanced. The outside dimensions were 82 x 82 m. A third site, C, was prepared for studying the growth and morphology of bluebunch wheatgrass (Chapter 3) in the Douglas fir community. The design was a 3 x 3 Latin square and the outside dimensions were 12 x 15 m. Sites A and B were fenced with barbed wire which was readily permeated by deer. Site C was not fenced and fall grazing was simulated by clipping with an electric powered sickle bar. Forage selection at all sites was measured as the proportion of plants grazed to plants ungrazed. The plants were sampled in a belt transects established parallel to the rows and across the plots. Ten transects were used at sites A and B and 6 transects at site C.

6.1.2.3 Migration and Distribution of Deer on Spring Range

An estimate of the relative seasonal distribution of deer use on spring range was made with night-time surveys

encompassing the fields described above and on additional spring range. Deer counts were made by an observer, using a 300,000 candle-power spotlight, standing at the back of a slow moving pick-up truck. Counts were made on 18 occasions from 18 February to 11 April, along the same 17 km transect. The counts were partitioned according to field to show changes in distribution.

6.1.3 Statistical Analysis

The treatment effect on bluebunch wheatgrass production and its subsequent utilization by deer and cattle was evaluated using analysis of variance and Duncan's multiple range test. Prior to analyses the utilization estimates were transformed to a percent of total available forage in each treatment. Estimates on the proportion of bluebunch wheatgrass contributed by each treatment were based on total utilization for that species. Consequently, the proportion contributed by the grazed treatment was based on four times the area of the others. Relative preference was calculated for each survey as described earlier.

Where the treatment effect was measured as a proportion of plants grazed, the data was first altered with the arcsine transformation. Since the values for the control were all zero, the response to the burned and grazed treatments were analyzed using the t-test.

Utilization of species other than bluebunch wheatgrass were estimated as the percent of cover removed. The

estimates were weighted among plots by available cover.

The effect of dead stubble on the utilization of spring forage of bluebunch wheatgrass was evaluated using regression analysis. The relationships were calculated at 3 levels of utilization with polynomial equations to the 3rd degree according to Goulden (1952).

The effect of grazing intensity on the homogeneity of utilization among sub-plots was examined using the coefficient of variation (CV). Utilization estimates were converted to a percent of total available forage and the CV was calculated for among sub-plots at each survey and for each treatment. The CV (Y) was plotted against percent utilization (X) for the respective treatment. Linear equations of this relationship were calculated for each data set.

6.2 Results

6.2.1 Studies on Confined Animals

The grazing treatment, in the deer trials, left an average stubble height (±1 SEm) of 7.7±.6 and 7.2±.2 cm in the big sagebrush and Douglas fir communities respectively. The stubble heights in the cattle trials were 5.8±.3 and 7.0±.2 cm in the same communities respectively.

Forage yield was less in treated plots than in control plots although the difference was significant ($P<0.05$) in only one trial (Table 28). The proportion of available bluebunch wheatgrass utilized by both deer and cattle was

Table 28. Effect of fall grazing or burning on the availability of bluebunch wheatgrass in two communities during April and May, 1977.

Community	Deer Trials April			Cattle Trials May		
	Control	Graze	Burn	Control	Graze	Burn
n=	12	48	12	48	192	48
Artemisia tridentata	2.1±.8a*	1.7±.2a	1.4±.3a	7.0±1.4a	4.9±.5a	6.2±1.3a
Pseudotsuga menziesii	5.3±.9b	3.5±.5a	2.0±.4a	12.1±1.3a	9.4±.6a	7.0±1.1a

* $gm/m^2 \pm 1$ SEm.
a&b Means with the same letter, in row of subset, do not differ significantly ($P > 0.05$).

highest from burned areas and lowest from control areas (Figures 12 and 13). The total proportion selected, however, was low from the burned treatment because availability was less. The burned and control areas were each 1/6th of the total area and the grazed, 4/6th. Furthermore, burning tended to decrease yields (Table 28).

Deer selected a greater proportion of forage from the grazed treatment than from the others (Fig. 12). The utilization trends in both communities were for increasing use of forage from the control and diminishing use from the grazed treatment. Deer demonstrated greater preference for bluebunch wheatgrass from the burned treatment at all levels of utilization. Bluebunch wheatgrass from the grazed treatment was preferred to that from the control in both communities except at the final two surveys in the Douglas fir community. Equal preference for the grazed and control treatments occurred when utilization of the former was 37% and, of the latter, 14%. Deer switched from the burned to the control when the former was utilized 73% and the latter, 9%.

Cattle utilized forage from the treatments in a similar manner between communities (Fig. 13). The most conspicuous difference was in the high utilization made of the control in the Douglas fir community. The proportion of both the grazed and burned treatments in the diet declined and the proportion of the control increased as utilization increased. Switching from the burn to the control occurred,

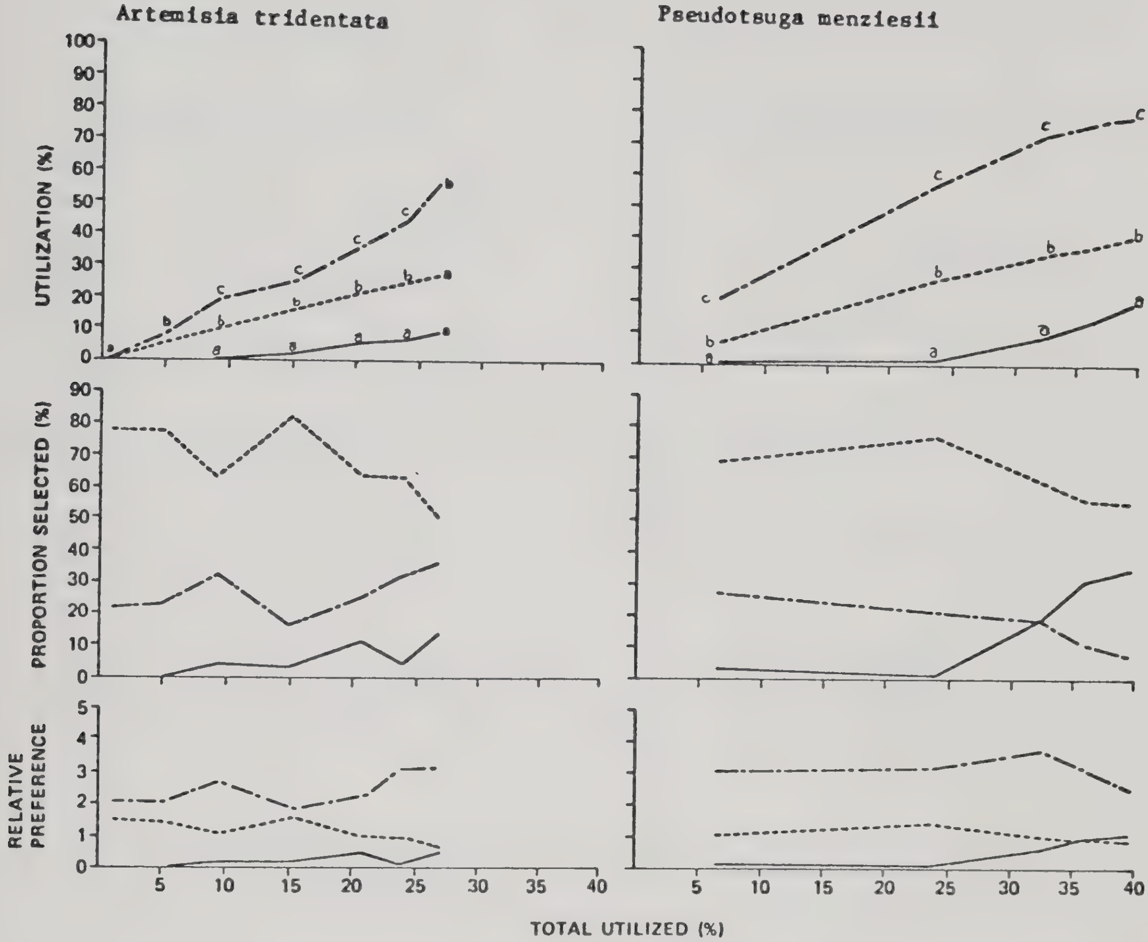

Figure 12. First year effect of fall treatment (control,——; clip,-----; burn,–·–·–) on the utilization, selection and relative preference of bluebunch wheatgrass by deer, relative to total utilization from all treatments, in two communities during April, 1977. Utilization differences between treatments that have different letters are significant ($P < 0.05$).

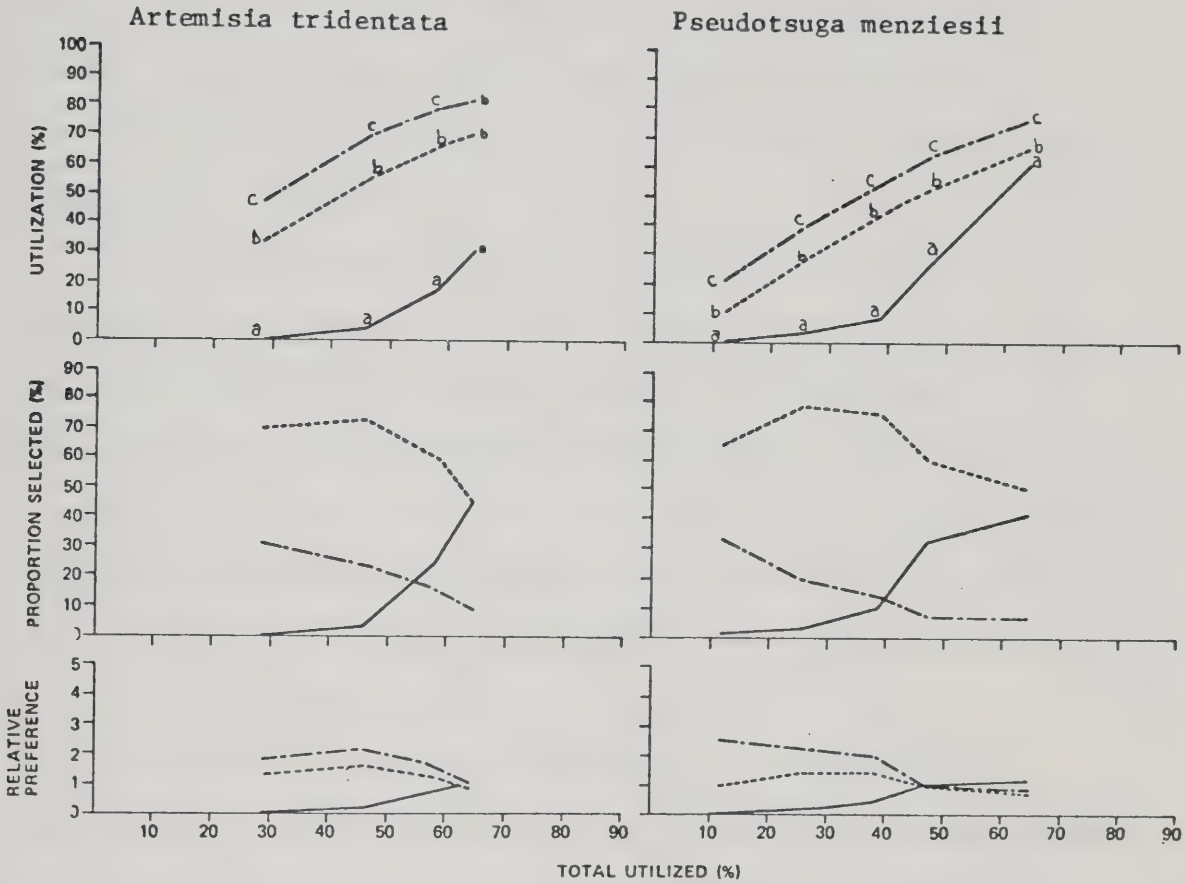

Figure 13. First year effect of fall treatment (control,——; clip,-----; burn,—·—) on the utilization, selection and relative preference of bluebunch wheatgrass by cattle, relative to total utilization from all treatments, in two communities during May, 1977. Utilization differences between treatments that have different letters are significant ($P < 0.05$).

in the big sagebrush community, when the former was utilized 76% and the latter 13% and, in the Douglas fir community, when the same treatments were utilized 56 and 12% respectively. Relative preferences among treatments were similar when the burned, grazed and control plots were utilized about 81, 69 and 29% respectively in the big sagebrush community and 65, 53 and 27% respectively in the Douglas fir community.

The cover of forb and grass species, other than bluebunch wheatgrass, and their degree of utilization are shown in tables 29,30 and 31. Sandberg's bluegrass, cheatgrass and needleandthread represented major proportions of cover in the big sagebrush community. In the Douglas fir community a variety of grass and forb species were similarly represented. The data was stratified into treatments only for the cattle trials (Tables 30 and 31).

The degree of utilization increased approximately linearly from the first to the last surveys but varied among species. Deer selected a greater proportion of available Sandberg's bluegrass and fleabane (*Erigeron* spp.) in the big sagebrush community. Sand dropseed (*Sporobolis cryptandrus*) was not utilized while cheatgrass and needleandthread were utilized in minor proportions. In the Douglas fir community, deer utilized species of the forb type (Table 29) most intensely although pasture sage (*Artemisia frigida*) and yarrow (*Achillea millefolium*) were scarcely utilized at the earlier surveys. Selection by cattle was distinguished from

Table 29. Available forage (% ground cover) of important species and their utilization by deer in two communities.

Species	Available forage % cover ($\bar{x}$±SEm)	% freq.	Survey Number 1	2	3	4	5	6	7
			Artemisia tridentata (n=48)						
CRASSES:									
Bromus tectorum	2.0± .6	38	0	tr*	3	11	13	14	15
Poa sandbergii	10.6±1.1	97	tr	2	17	35	54	61	68
Stipa comata	.2± .1	14	0	0	8	23	29	29	30
Sporobolis cryptandrus	.2± .1	46	0	0	0	0	0	0	0
FORBS:									
Erigeron sp.	.5± .1	35	0	1	22	45	64	67	69
			Pseudotsuga menziesii (n=48)						
GRASSES:									
Aristida longiseta	3.4± .8	46	0	0	0	0	0		
Koeleria cristata	1.4± .3	57	3	8	42	62	75		
Poa sandbergii	2.3± .7	25	5	5	19	34	38		
Stipa comata	.9± .2	35	0	0	2	13	20		
FORBS:									
Achillea millefolium	.6± .2	35	1	1	2	15	43		
Artemisia caudatum	.3± .1	28	10	10	45	65	74		
Artemisia frigida	.5± .3	21	0	0	9	29	54		
Astragulus sp.	.3± .1	26	16	28	54	73	86		
Tragopogon dubius	.1± .04	14	26	52	65	85	100		

* Less than .5%

Table 30. Available forage (% ground cover) of important species and their utilization by cattle in relation to treatment in the *Artemisia tridentata* community.

Treatment and Species	Available forage		Forage utilized (% of available cover grazed)			
	% cover ($\bar{x}$±SEm)	% freq.	Survey Number 1	2	3	4
CONTROL†						
Grasses:						
Bromus tectorum	5.0± .9	94	tr*	7	27	44
Poa sandbergii	7.1±1.1	94	0	3	8	15
Stipa comata	7.4±1.7	67	0	1	17	45
Forbs:						
Calochortus macrocarpum	.6± .2	25	0	8	25	40
Erigeron spp.	.4± .1	31	0	6	39	50
Lomatium macrocarpum	.1± .1	21	0	21	38	62
GRAZE‡						
Grasses:						
Bromus tectorum	11.3±1.0	90	5	18	31	42
Poa sandbergii	15.6±1.2	91	tr.	3	7	13
Stipa comata	4.3± .4	62	46	67	80	88
Forbs:						
Erigeron spp.	.6± .1	46	6	23	48	59
Lomatium macrocarpum	.4± .1	24	13	39	39	39
Tragopogon dubius	.2± .1	18	42	84	93	94
BURN†						
Grasses:						
Bromus tectorum	9.0±1.7	92	5	17	19	39
Poa sandbergii	7.5±1.1	85	tr.	3	9	24
Stipa comata	7.8±1.0	58	53	87	90	95
Forbs:						
Calochortus macrocarpum	.5± .2	19	29	32	51	61
Erigeron spp.	.5± .1	35	2	22	42	55
Lomatium macrocarpum	.3± .1	25	13	57	64	84
Tragopogon dubius	.2± .1	25	21	69	69	69

† n=48; ‡ n=192

* Less than .5%

Table 31. Available forage (% ground cover) of important species and their utilization by cattle in relation to treatment in the *Pseudotsuga menziesii* community.

Treatment and Species	Available forage: % cover (x±SEm)	Available forage: % freq.	Forage utilized (% of available cover grazed), Survey Number: 1	2	3	4	5
CONTROL†							
Grasses:							
Aristida longiseta	1.3± .4	27	0	0	tr*	1	43
Koeleria cristata	1.4± .2	67	16	27	40	56	86
Forbs:							
Achillea millefolium	.5± .1	29	0	3	17	32	62
Artemisia caudatum	.5± .1	42	0	4	20	24	55
Astragulus spp.	.6± .1	38	12	20	45	72	93
Gailardia aristata	.1± .1	12	0	38	55	59	79
Oxytropis campestris	2.7±1.0	40	29	54	74	80	94
Tragopogon dubius	.3± .1	27	33	62	86	86	97
GRAZE‡							
Grasses:							
Aristida longiseta	2.1± .5	23	tr.	1	4	8	60
Koeleria cristata	1.4± .1	64	22	40	60	74	85
Stipa comata	.3± .1	10	3	26	57	67	80
Forbs:							
Achillea millefolium	1.0± .1	43	2	10	27	33	60
Antennaria spp.	.3± .1	20	0	tr.	10	28	36
Artemisia caudatum	.5± .1	43	tr.	1	16	28	65
Astragulus spp.	.8± .1	40	2	19	42	73	93
Gailardia cristata	.3± .1	21	10	45	72	78	86
Oxytropis campestris	2.1± .6	27	48	61	77	93	96
Tragopogon dubius	.5± .1	38	42	67	84	92	98
BURN†							
Grasses:							
Aristida longiseta	.2± .1	4	0	0	10	10	50
Koeleria cristata	1.1± .2	58	21	32	40	60	83
Stipa comata	.04± .03	4	0	0	50	100	100
Forbs:							
Achillea millefolium	1.0± .2	52	2	4	27	32	60
Antennaria spp.	.2± .1	17	20	20	20	23	24
Artemisia caudatum	.2± .1	27	15	20	31	43	70
Astragulus spp.	.6± .2	29	6	13	39	61	91
Gailardia cristata	.2± .1	21	0	23	51	64	91
Oxytropis campestris	4.0±1.3	46	35	57	75	83	94
Tragopogon dubius	.4± .1	27	54	87	89	92	99

† n=48; ‡ n=192

* Less than .5%

deer by the degree of utilization among species. In the big sagebrush community, cattle utilized most of available needleandthread and minor proportions of available Sandberg's bluegrass (Table 30). Needleandthread was also heavily utilized in the Douglas fir community. The forbs, however, were heavily utilized by cattle in a similar manner as by deer. Vetch (Astragulus spp.), crazyweed and salsify (Tragopogon pratensis) experienced exceptionally heavy use.

Tables 30 and 31 also define selection differences for individual species among treatments. Initial utilization of a species, in both communities, was greater on the treated than on the control plots. This difference extended through to the final survey in the big sagebrush community. In the Douglas fir community, however, the degree of utilization at the final survey was similar among treatments.

The effect of dead stubble on grazing of spring forage was examined using regression techniques (Table 32). Within a data set, the Y-intercept and regression coefficient usually decreased and the coefficient of determination (r^2) increased with greater utilization. Deviation from this generalization occurred in the small circumference class. In general, the regression coefficient and r^2 of the larger circumference class were greater than those of the smaller class, comparable for trial and degree of utilization (Table 32). The equations indicate the barrier effect was inversely proportional to stubble length and forage availability.

Variation of utilization among sub-plots declined in a

Table 32. Effect of dead stubble (X, cm) on the grazing height (Y, cm) of bluebunch wheatgrass by deer during April and by cattle during May. The effect was measured for plants of 2 size classes, at 3 levels of utilization and in 2 communities.

			Plant base (circumference of plant)					
			< 20 cm			> 20 cm		
Community	Species	Utilization (%)	Equation	r^2	n	Equation	r^2	n
Ar	Deer	9	Y = 6.47+.410a X	.21	71	Y = 5.15+.813b X	.43	63
		21	Y = 3.31+.476a X	.52	71	Y = 3.96+.624ab X	.35	62
		27	Y = 2.42+.481a X	.42	71	Y = 2.74+.596ab X	.45	62
Ps	Deer	7	Y = 9.53+.668ab X	.13	70	Y = 9.55+.898b X	.24	74
		27	Y = 5.43+.380ab X	.06	70	Y = 4.12+.644ab X	.26	75
		37	Y = 3.02+.387a X	.51	70	Y = 2.48+.592a X	.62	75
Ar	Cattle	33	Y =10.70+.510ab X	.10	75	Y = 8.03+.744b X	.37	75
		54	Y = 6.65+.504ab X	.17	75	Y = 4.64+.524ab X	.51	75
		70	Y = 3.25+.446a X	.24	75	Y = 2.47+.467a X	.61	75
Ps	Cattle	10	Y =25.37 .099a X	$.01^{NS}$	75	Y =29.13+.676c X	.12	75
		45	Y =11.51+.443c X	.17	75	Y = 9.30+.542c X	.19	75
		67	Y = 6.79+.135ab X	.06	73	Y = 5.08+.348c X	.35	74

† All equations, with one exception (NS), are significant ($P < 0.05$).

a&b Regression coefficients, with same letter, within subset of community and species, do not differ significantly ($P > 0.05$).

Ar.tr. *Artemisia tridentata*; Ps.me. *Pseudotsuga menziesii*.

logarithmic manner with increased utilization (Table 33). In the deer trials, the regression coefficients of the burned treatment in both communities were larger than for the other treatments. The treatment effect was not reported for the cattle trials where visual examination of plotted data did not reveal differences. Regression coefficients were larger for equations of the Douglas fir community than for equations of the big sagebrush community.

6.2.2 Studies on Free-Ranging Animals

6.2.2.1 Forage Selection by Cattle

Free ranging cattle utilized bluebunch wheatgrass from the treated plants significantly more ($P<0.05$) than from the control plants (Table 34). At the only site (D) where both burned and grazed treatments were present, plants of the grazed treatment were utilized more than plants of the burned treatment. However, this difference was significant only at survey 1.

The degree of utilization among sites appeared similar for the grazed treatment at each survey. There was no relationship of the proportion fall grazed to fall ungrazed plants (Table 27) with the degree of spring utilization. grazed treatment. However, utilization of the control plants decreased as their proportion on the range increased (Tables 27 and 34).

Table 33. Effect of grazing intensity (X) on the variation of forage removed (Y) in relation to treatment, animal species and community.

Community	Species		Equation	r^2	n
			Individual treatment		
Ar	Deer	Control	Log Y=2.234-0.286a(Log X)	.95	6
		Graze	Log Y=2.197-0.199a(Log X)	.95	7
		Burn	Log Y=2.321-0.439b(Log X)	.92	7
Ps	Deer	Control	Log Y=2.272-0.434a(Log X)	.85	5
		Graze	Log Y=2.684-0.600a(Log X)	.99	5
		Burn	Log Y=3.967-1.448b(Log X)	.92	5
			Treatments combined		
Ar	Deer		Log Y=2.227-0.304c(Log X)	.84	20
Ps	Deer		Log Y=2.423-0.522d(Log X)	.72	15
Ar	Cattle		Log Y=2.350-0.535d(Log X)	.84	12
Ps	Cattle		Log Y=2.769-0.741d(Log X)	.89	15

Y Coefficient of variation; X Percent utilization.

a&b Regression coefficients, with the same letter, within subset of habitat and species, do not differ significantly (P > 0.05).

c&d Regression coefficients, with the same letter do not differ significantly (P > 0.05).

Ar *Artemisia tridentata*; Ps *Pseudotsuga menziesii*.

Table 34 Effect of fall grazing or burning on the proportion (%) of bluebunch wheatgrass plants grazed by free ranging cattle at five sites.

Site†	Survey 1			Survey 2			Survey 3		
	Control	Graze	Burn	Control	Graze	Burn	Control	Graze	Burn
A $\bar{x}$: (n=138 to 162)	4.5a	25.9b	--	13.9a	35.5b	--	24.3a	49.2b	--
B $\bar{x}$: (n=63 to 117)	4.9a	27.94b	--	13.9a	43.9b	--	22.8a	52.5b	--
C $\bar{x}$: (n=300)	1.4a	26.3b	--	5.2a	41.4b	--	14.8a	50.7b	--
D $\bar{x}$: (n=66 to 134)	0.2a	24.0c	5.4b	2.4a	46.7b	39.2b	5.6a	59.0b	49.2b
E $\bar{x}$: (n=200)	1.9a	--	42.1b	2.0a	--	56.8b	4.1a	--	59.0b

† Described in table 1.
a-c Average within subset of each survey, with same letter do not differ significantly ($P < 0.05$).
n Number plants per treatment.

6.2.2.2 Forage Selection by Deer

There were no observations where free-ranging deer selected control plants of bluebunch wheatgrass (Table 35). In the Douglas fir community (Sites B and C), deer selected about twice the proportion of plants from the burned treatment as from the grazed treatment. Selection in the big sagebrush community (Site A) favoured the burned treatment as well but the difference was not significant ($P>0.05$).

6.2.2.3 Migration and Distribution of Deer on Spring Range

The number of deer sightings made on the spring range increased linearly with time (Fig. 14) although examinations of the plotted data indicate a slight sigmoidal change. Two hundred and sixty eight animals were observed on two fields from 18 February to 11 April. The incidence of sightings increased in approximately the same manner as on the total spring range. From 18 February to 29 March, 147 sightings were made which were distributed in a ratio of 1:4.2 between the fall grazed and fall ungrazed fields. During the remaining time, to April 11, 121 sightings were distributed in a ratio of 1:1.1 between the fields. If the sightings were weighted according to the area surveyed in each field the first ratio becomes 1:2.2 and the second 1:0.6.

Table 35. Effect of fall grazing (or clipping) or burning on the proportion of bluebunch wheatgrass plants grazed by free-ranging deer at three sites.

		Control		Grazed		Burned	
Site+	Date of Survey	n	Proportion grazed	n	Proportion grazed	n	Proportion grazed
A	27 April	159	0.00a	576	0.33b	146	0.44b
B	29 April	436	0.00a	1700	0.14b	383	0.30c
C	16 April	133	0.00a	89	0.21b	111	0.45c

\+ Site A in *Artemisia tridentata* community; Sites B and C in *Pseudotsuga menziesii* community.

a–c Proportion with same letter in row do not differ significantly ($P > 0.05$).

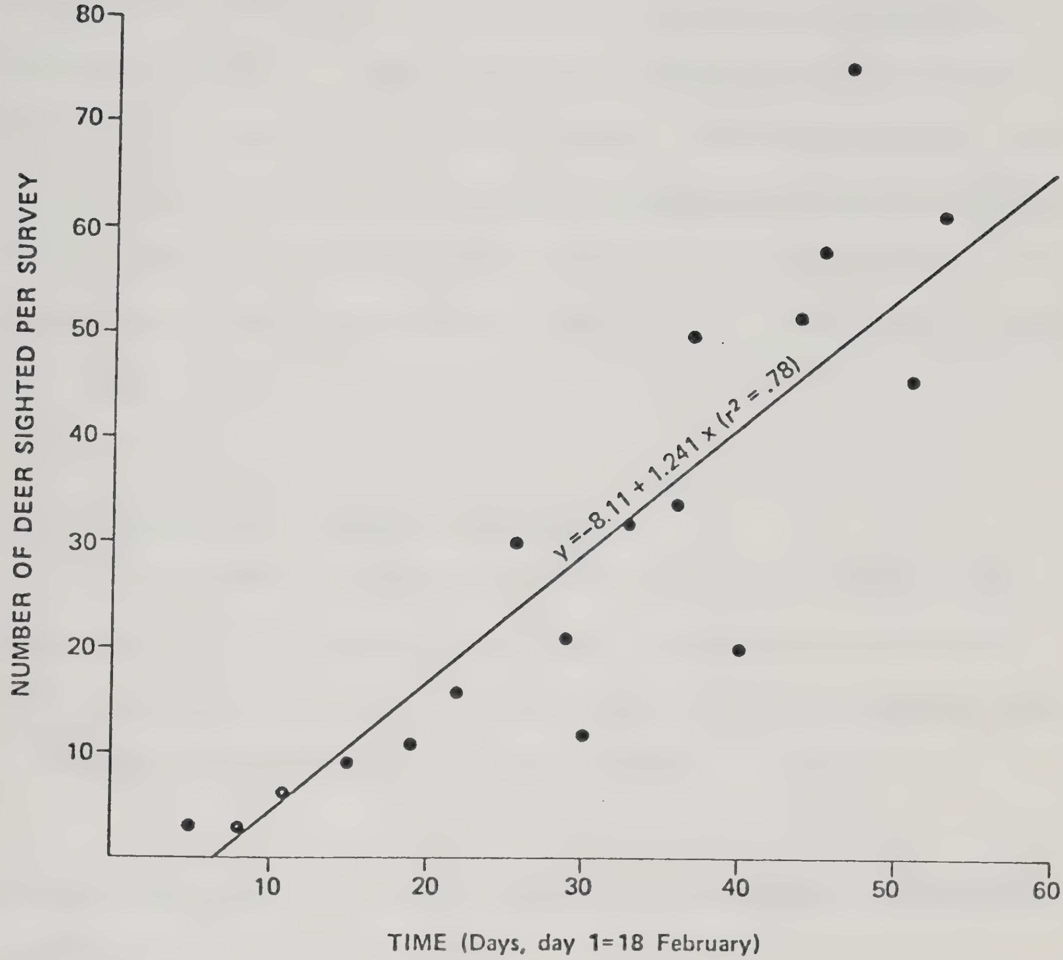

Figure 14. Migration of deer (night time sightings per survey) onto spring range from 18 February to 11 April, 1977.

6.3 Discussion

Forage availability was affected by the proportion of area treated and by the production in each. The proportion of area burned in the first study was similar to that suggested by Duvall and Whitaker (1964) and Grelen and Whitaker (1973) for southern U.S. ranges. In the second study, the proportion of area burned was considerably below an acceptable level for a range management program (Wright 1974). Results of the studies in this section relate implicitly to forage availability and animal preference for each forage class.

6.3.1 Studies on Confined Animals

The treatment effect on productivity was similar to that observed in chapter 5. It was evident that burning reduced production in the first year although recovery may have enhanced production in the second.

6.3.1.1 The Effect of Fall Clipping or Burning on Forage Selection

Bluebunch wheatgrass selection among treatments was also similar to those reported earlier. The result of altering the proportion of treated areas did not change appreciably the relative preference for each treatment. This indicates that for the range of proportions for burn:graze:control areas of 1:1:1 to 1:4:1, consumption of each was a linear response to availability. An obvious

qualification to this generalization is that area was not necessarily related to availability. Furthermore, with preferential selection among treatments, the ratio of available forage was continually altered. Their combined effect would be to reduce the proportion of available forage from the burned treatment and increase the proportion from the control.

The relative preferences, determined among both deer and cattle trials, show three general trends with increased utilization, all based on the burn treatment. The trends were: an increase (Fig. 12); a decrease (Fig. 13); and an initial increase followed by a decrease (Figures 12 and 13). These trends may be explained on the basis of foraging tactics discussed above, where selection for a declining forage becomes greater to complete a meal; followed by switching to compensate for an unprofitable selection. The changing preferences for the clipped and control treatments may be explained on similar logic. Discrepancies among trials appear to be the result of insufficient grazing pressure in one case (Fig. 12) and an unusual decline in relative preference at moderate grazing intensity in another case (Fig. 13).

Although the study investigated the treatment effect on bluebunch wheatgrass, this species was not the only forage utilized and may not have been the most preferred. For instance, the proportion of available Sandberg's bluegrass utilized by deer in the big sagebrush community (Table 29)

was considerably greater than the proportion of bluebunch wheatgrass. Similarly, most forbs were utilized to a greater degree by deer in both communities than was bluebunch wheatgrass. Vetch and salsify appeared most highly preferred. Cattle also utilized large proportions of forage other than bluebunch wheatgrass. Utilization of those forages appeared affected by treatment, particularly in the early stages of grazing (Tables 30 and 31).

The influence that one species has on the selection of another cannot be deduced from information found in tables 30 and 31, however, an inference may be made. It appears that selection of another species was influenced by association with bluebunch wheatgrass. The data shows that percent utilization of all species was proportionately similar, among treatments, to bluebunch wheatgrass utilization. Support for this argument also comes from the theory on foraging tactics (Ellis et al. 1976). That is, when nutrients are not limiting, more effort can be expended to search for scarce, but more preferred forages. In the communities studies, bluebunch wheatgrass provided the most important nutrient source.

Availability and utilization estimtes based on ground cover are not comparable among species. More refined estimates may be made using regression techniques similar to those of Payne (1974). Percent utilization of available forage was, apparently, comparable to percent cover grazed because the species growth form was low thus requiring close

utilization.

6.3.1.2 Effect of Stubble on Forage Selection

The greater preference and utilization of burned forage was at least partly the result of shortened stubble. This was demonstrated by regression equations developed from plants of the grazed treatment (Table 32). For example, the relative preferences for forage within a plant, having a circumference greater than 20 cm, and calculated for cattle in the big sagebrush community at 54% utilization, changed from 6.1 at zero stubble to .7 at stubble the height of the total plant. These estimates were based on calculations defined earlier for relative preference and for the proportion utilized from equations describing the relationships of weight to height defined in chapter 3.

The equations predicting grazing height (Table 32) reveal a diminishing effect as both stubble length and grazing pressure increase. The interaction of increased grazing pressure on the stubble was demonstrated by both a decreasing Y-intercept and regression coefficient for all combinations of animals, communities and plant sizes. A stubble effect uniform with height would have a regression coefficient of 1 in the equation. This was most closely achieved by deer on larger plants with very light utilization. Normally, as grazing pressure increased the deer foraged below the height of mature stubble while cattle probably depressed the stubble length by utilizing it with

new forage. Consequently, the point at which the grazed height equalled the original stubble height declined with increased utilization. According to the size of the r^2 and regression coefficient, cattle were influenced less by the stubble than were deer. The contrast was particularly evident with smaller plants.

As expected, the stubble of small plants imposed a less effective barrier than the stubble of large plants. This appeared largely offset by less utilization of the very small plants. This is inferred from the generally larger Y-intercept of their regression equations. Presumably the small plants were either not sensed by the herbivore or were avoided.

6.3.1.3 The Effect of Fall Grazing or Burning on the Homogeneity of Range Utilization

The logarithmic equations (Table 33) indicate that utilization variability declined rapidly from light utilization (10%) and reached near stability at about 50% utilization. Deer utilized burned areas more uniformly than areas of other treatments. On the other hand, cattle utilized the big sagebrush range more uniformly than did deer. Deer exemplified a more selective feeding behavior that resulted in greater utilization variability among plants.

6.3.2 Studies on Free-Ranging Animals

6.3.2.1 Forage Selection by Cattle

The sites selected for study (Table 27) varied in community, treatment and the proportion of plants previously grazed. Furthermore, grazing pressure could not be controlled for uniform distribution over the entire field. The most valid comparisons were between treatments. Inferences on the effect of site conditions may also be made.

The relative utilization between the grazed and control plants was similar to that reported earlier (Chapter 3). However, on site D where the grazed and burned treatments occurred together, utilization differed considerably from the previous study. The reason for this is not clear. An explanation may be found in the size and shape of area burned. The burn at site D was small and irregular, perhaps making selection for plants of that treatment unprofitable.

Utilization of forages in all treatments increased gradually through the grazing period. Only in the burned area of Site E was initial utilization heavy. Grazing on that site occurred immediately after cattle were released into the field. Over fifty head, including both yearlings and adults, were herded past the site without detecting the burned area. When released they began to graze in the direction which led directly to the burn. They moved over the area but only a few animals lingered to search for residual forage, and not all animals seemed to have entered

the burned area. Observations throughout the grazing period indicated a few animals frequented the site. It was not known if the animals were the same individuals at each observation.

Utilization differences among sites of the fall-grazed plants were minor. However, utilization differences of control plants, among sites, varied considerably. Their utilization decreased from the big sagebrush community to the ecotone and to the Douglas fir community. The proportion of plants grazed the previous fall did not appear to be a factor.

It is noteworthy that minor use was made of control plants of bluebunch wheatgrass in both communities. This occurred despite the severe over-use of crested wheatgrass on the flat field (personal observation). Presumably, average utilization over the entire range approached the recommended levels, however, uneven distribution resulted in inefficient use of the forage resources.

6.3.2.2 Forage Selection by Deer

The method of determining selection, by estimating the proportion of plants used from each treatment, describes the olfactory and tactile preferences. The relatively small plots available to free-ranging deer permitted ready access to all choices and encouraged greater utilization. Lack of control on the stocking rate of deer makes the importance of absolute values irrelevant.

Wild deer displayed a response similar to that observed by captive animals in study 1. The treatment effect was more pronounced in the Douglas fir community (Sites B and C; Table 8), perhaps the result of greater plant density. Deer appeared to rely on tasting then rejecting or accepting forage to gain experience for completing their meal. This mechanism requires that a minimum number of plants are tested. Consequently, where plant density is low, the proportion selected is increased. The selection mechanism described is based on chemical factors for discrimination but precludes the control plant from selection because of its' physical barrier of standing litter.

The small size of plots used for observation do not typify conditions normally accessible to free-ranging deer. Observations of plant selection made on larger burns (1.5 to 1 ha) in the vicinity of the study revealed light use. Only 13% of available plants were selected in late April and early May in two burns in the Douglas fir community. At the same time about 50% of the plants grazed in the fall were utilized by deer. These observations conflict with observations made on the smaller areas. An explanation can only be offered in terms of availability and distribution of plants from each class. The burned plants were grouped within a small area while the fall-grazed plants were widely dispersed among fall-ungrazed plants. Personal observation indicates that deer may travel extensively while feeding. This behavior would favor selection of dispersed plants

since fewer encounters with preferred plants would be ignored.

6.3.2.3 Distribution of Deer on Spring Range

A measure of both regional and local distribution of use was provided with deer counts. The region was the spring range where migration increased gradually, beginning in late February and extended through until early April (Fig. 14). The maximum count was made on 5 April. Although only two subsequent surveys indicated a decline, the trend established was supported by unscheduled, partial surveys of the area.

Migration by deer onto spring range does not follow a fixed schedule. Movement from their fall and winter range to the lower spring range appears to be in response to two pressures. One is a positive response to spring production of grass and the other is a negative response to deep snow at higher elevations. The effect is similar but spaced in time. In the first case, deer use the spring range when new production becomes available. Observations during five years indicate that total use is also modified by range quality, including forage palatability and productivity. Extremely light use occurred in one year when drought conditions prevailed resulting in reduced production and advanced forage maturity.

Further observations of free ranging deer indicate that vertical movement is diurnal as well as seasonal.

Observations of the first tracks in winter indicate that deer occupy the lower range overnight and leave by morning. Such forays indicate that range readiness is "tested" since the population becomes less transitory as available forage increases.

7. GENERAL DISCUSSION

Forage selection and utilization are affected by physical and chemical plant properties. Of the physical properties examined, tiller density, tiller weight and tiller height are the more important characteristics since they define both forage production and forage accessibility. Productivity of smooth brome has been related to tiller density and, to a lesser degree, to canopy height (Tan *et al.* 1977). Tiller weight and density define yield. Allden and Whittaker (1970) found that leaf length was important in determining bite size in sheep and, therefore, dry matter capture rate. The rate and height of plant growth, modified by the distribution of weight within a plant, determines availability and, indirectly, bite size.

7.1 Plant Morphology and Growth

The effect of fall defoliation was to move the relative distribution of dry matter to a lower position in the plant (Chapter 3), shorten plant height (Table 25) and reduce production (Tables 16, 17 and 28). These effects were similar to those reported by Rickard *et al.* (1975), Uresk *et al.* (1976) and Sauer (1978), and most pronounced in plants of the burned treatment. The effects appear to be related to temperature and light regimes of the plants modified by litter removal and darkening of the soil by burning. Shading increases leaf area, which is largely

determined by blade length, (Taylor *et al.* 1968; Kolker and Kigel 1972) while temperatures, above optimum for growth, result in reduced leaf area (Taylor *et al.* 1968). Removing shade also increases evapo-transpiration from the plant and evaporation from the soil. This may lead to an earlier than normal water deficit and, consequently, reduced production.

The shortened leaf length and lower distribution of dry matter appears to be a protective response. This is not only a protective response to a more severe micro-climate but also to the grazer. Plants with shorter leaves and a larger proportion of weight near the ground usually have a greater proportion of photosynthetic surface remaining after grazing. Furthermore, as foliage height decreases, the relative benefit of selecting that forage becomes progressively less. This effect will eventually cause cattle to switch to another forage (Part II).

Few treatment effects on the plant were apparent in April of either year. Presumably cooler temperatures during that month and sufficient soil moisture prevented the negative treatment effects. By May, however, detrimental effects had become apparent. This was particularly noticeable in the big sagebrush community where differences, both in production (Table 17) and plant height (Table 25), were evident. Shade from the trees evidently lessened the effect of darkened soil on the burned plots.

Forage production may be expected to increase after the first year of burning. The effect appears to be the result

of greater tillering in those plants.

7.2 Time of Burning

Conflicting evidence has been reported on the effects of burning on bluebunch wheatgrass productivity. Some report no first year effect on plant vigor (Uresk *et al*. 1976) and others report decreased vigor (Conrad and Poulton 1966). It is evident from this study that time of burning was critical. Although climatic conditions differed, they were not considered as important a factor as time since burning. The most important difference was likely the position of tiller apices. The March burn coincided with the appearance of new tillers at the ground surface (Fig. 5) thus making them susceptible to heat damage. Daubenmire (1968) considered 60°C to be a critical temperature for damage to meristematic tissue. This temperature is readily attained in the crown of grasses during grassland fires (Bailey and Anderson 1979). Since fall regrowth was destroyed by both burns the major effect was only on spring initiated tillers.

7.3 Plant Chemistry

Fall clipping or burning affects both nutrient concentration (Figures 1 and 2) and dry matter distribution in the plant which, in turn, determine nutrient distribution. The dry matter distribution has been defined with polynomial equations (Tables 2 and 6). According to

these equations, and data on mineral concentration in the plant (Table 13), estimates of nutrient harvest can be made at any level of utilization. For example, in the big sagebrush community in May, grazing 60% of plant height would remove 36, 31 and 32% of dry matter in plants of the control, clip and burn treatments respectively. This grazing level would remove 52, 40 and 38% of available nitrogen in the same treatments. On the other hand, grazing 90% of plant height would remove 82 and 79% of dry matter in the control and defoliated treatments respectively while removing 93, 86 and 85% of nitrogen in the control, clip and burn treatments respectively. Although a greater proportion of nitrogen was distributed near the base of burned plants, total plant nitrogen was 20 and 15% greater than in control and clip plants of equal weight. The result was that, by removing 60% of plant height, a similar amount of nitrogen would be removed among treatments.

Grazing imposed in the first year after treatment appeared to modify the relative nutrient concentrations among treatments. Evidence for this was in a shift of higher nitrogen and lower NDF values in May from the burn treatment in the first year to the graze treatment in the second year. The nutrient rank among treatments in the April samples was not affected.

Grazing may have affected the chemical change by the time of defoliation and by the type of grazer. The April forages were grazed by deer and the May forages by cattle.

Although percent green forage utilization among treatments was similar for both animals (Part II), deer avoided mature litter while cattle utilized it when grazng pressure was high. The effect of grazing in May was to stimulate tillering beyond that achieved by treatment (Chapter 3). Furthermore, available nutrients in the second year were, presumably, from microbial decomposition and therefore limiting. The effect of a greater number of tillers drawing on a fixed nutrient source would be to reduce the concentrations in the plant. Grazing in April did not increase tillering in the second growing season beyond the stimulation provided by treatment.

7.4 Effect of Fall Defoliation on Plant Selection

Forage selection is closely related to consumer preference and forage availability as shown by the equation: Proportion consumed = Relative preference x Proportion available. Although this equation indicates a linear response of consumption to availability, that is not necessarily true because relative preference for a forage may also change with availability. Two tactics may determine the change in preference as the proportion of an available food decreases. One is to increase the search effort thus increasing preference for the food. This would agree with the theory of food selection proposed by Westoby (1974) that herbivores select a meal to optimize nutrition. The second change would be to reduce selection, or switch to another

species, thus reducing preference for the former. The latter tactic may result when the search effort becomes unprofitable (Moriarty 1977). The theory of food selection by Westoby (1974) may also explain a decline in preference as available food increases.

An hypothesis of forage selection based solely on the barrier effect of standing litter would be rejected on the basis of evidence from this study. Selection differences between the clip and burn treatments would not be expected at the beginning of each grazing trial if the presence of standing litter was the only criterion for selection. At this time, and throughout the grazing trials in the second year, the stubble effect was similar among treatments. Apparently plant chemistry also influenced selection.

7.4.1 Effect of Standing Litter

The high preference shown by both deer and cattle for the burned treatment could largely be attributed to the removal of standing litter. Litter created a barrier effect limiting access to spring growth. This effect was present in control plants at all levels of utilization and, in the clipped and burned plants, when grazing reduced the foliage height to that of stubble. Since burning reduced the stubble height to near ground level, the barrier effect was most important with clipped plants. Accordng to the equations derived for the relationship between spring grazing heights and stubble heights (Table 32), deer and cattle may graze to

within 1 and 2 cm, respectively, above a 2 cm stubble. This relationship was influenced both by grazing intensity and habitat differences. Presumably, the greater proportion of litter in the Douglas fir community established a more effective barrier. With taller stubble the animals were capable of grazing to, or below it's height. Both deer and cattle appeared to be equally affected by 10 cm stubble.

Weathered forage is not preferred and it acts as a barrier to both deer and cattle. Only deer, however, were able to avoid it. The author observed very few instances where weathered forage was selected by deer yet cattle utilized it in proportions similar to that of green forage.

Selective grazing permitted deer to maintain a near constant proportion of each treatment in their diet. This resulted, with one exception (Fig. 1), in a consistent order of preference among treatments despite grazing intensity.

7.4.2 Effect of Plant Chemistry

First and second year preferences for the burn treatment reveal that selection for a chemical factor does exist. Although nutritive properties are altered by burning, and are related to palatability (Heady 1964), properties such as crude protein and energy probably cannot be sensed by the animal (Arnold and Hill 1972). Secondary compounds have been shown to affect palatability (Arnold and Hill 1972; Freeland and Janzen 1974).

Westoby (1974) addressed the problem of nutritional

wisdom in large herbivores and modelled food selection by basing it on a strategy to optimize nutrient balance. Perhaps the most convincing argument that nutritional wisdom exists is that herbivores need it. The argument against nutritional wisdom is that no direct evidence is available for it. Martin (1969) cites numerous references which associate nutritive constituents with palatability and highlights the discrepancies which exist in the literature. Heady (1964) reviewed the factors affecting forage palatability, demonstrating the interaction which may occur to produce inconsistent results of forage selection. Examples of variable response were described by Gordon (1970). Freeland and Janzen (1974) suggest ruminants select food in order to detoxify secondary compounds. This leads to conservative feeding and testing of numerous species. Arnold and Hill (1972) discount the question of nutritional wisdom in ruminants due to the lack of relevant data. They note that ruminants, like all animals, select food on the basis of their senses, of which taste is an important one, and that most components of proximate composition cannot be detected.

Studies reported in this thesis demonstrate a well defined order of preference for bluebunch wheatgrass among fall treatments. Both deer and cattle preferred the burned to the clipped, and both to the control plants. This appeared to demonstrate selection for nutrients since they declined in the same order among treatments. However,

several observations negate this conclusion. One, the nutrients were similar among treatments near the top of the plants; two, preference for the burned treatment increased with increased grazing despite a decreasing nutrient level; and three, nutrition from any treatment was not limiting, hence selection for that factor would not benefit the animal. Although stubble affected selection at high levels of utilization, preferential selection of the burned to the clipped forage at early grazing indicates selection for factors other than nutrients. Secondary compounds may be expected to change among treatments, as the nutritive properties do, because of their interrelationships.

Little evidence is available on the nutritive value of standing litter resulting from prior burning or grazing. Pearson *et al*. (1972) studied the nutritive quality of forage resulting from a spring burn. They found higher crude protein, phosphorus and *in vitro* digestibility in the first growing season but no difference in the second; similar results were found by Allen *et al*. (1976) on bluestem range. The effect of fall grazing on the nutritive properties of bluebunch wheatgrass appear minor (Rickard *et al*. 1975; Willms *et al*. manuscript in preparation). There appears to be no basis for range burning simply to increase forage nutrition in spring, when nutrient quality is not limiting, or in fall when the effect is noticeable for only one season.

7.5 Management Implications

The spring range is important to deer in providing the earliest available, high quality forage. Willms *et al.* (1976) found that the diet consisted mostly of grass in early April; the greatest proportion of this was Sandberg's bluegrass (Willms and McLean 1978). This shallow rooted species produced forage earliest and mature stalks do not persist through the winter. Cattle do not utilize this species in the fall hence do not directly affect its palatability and vigor. The effect of fall burning on the palatability of Sandberg's bluegrass is not known. However, Wright and Klemmedson (1965) report no effect of fall burning on plant vigor. The productivity of Sandberg's bluegrass is highly variable and it loses palatability early in spring. These characteristics reduce the importance of this species, particularly since its long term benefit is determined by minimum production, and focuses attention on the deeper rooted perennials.

Initiation and appearance of tillers determine, at least in part, the time of available forage. This is particularly true for deer who depend on new foliage from grass to offset the nutrient deficit of winter (Fierro 1977, Willms and McLean 1978). Forage availability in spring will depend on the stubble height of bluebunch wheatgrass.

Observations reported earlier (Chapter 3) indicate bluebunch wheatgrass appeared at ground level after 10 March in the big sagebrush community and after 21 March in the

Douglas fir community. This forage was available to the herbivore within a few days depending on the stubble height of standing litter. When stubble is greater than 10 cm tall (Part II), spring growth would not become available until late March or early April in the big sagebrush community and 10 or more days later in the Douglas fir community. The presence of fall regrowth will modify these estimates according to its length.

Spring growth of crested wheatgrass and Sandberg's bluegrass will become available soon after appearing at ground level. Their weathered forage is a less effective barrier than the standing litter of bluebunch wheatgrass. The litter of crested wheatgrass is often decumbent while the litter of Sandberg's bluegrass is weathered to a fine, sparse mass.

These effects were believed reflected in the local distribution of deer between the fall-grazed and fall-ungrazed fields. The effect of fall grazing should have reflected in the population distribution soon after wheatgrass tillers appeared at the ground surface, in early March, if stubble height was zero. In fact, no shift to the grazed field was apparent until early April when, presumably, the spring growth extended above the stubble. The relatively little use made of the fall-grazed field prior to April is not understood. Food, however, did not seem to be a factor since the same habitat types were present in both fields. In other work, Leckenby (1968) found

a 3-fold increase in crested wheatgrass utilization by deer where the standing litter had previously been removed.

The observation has frequently been made that light and moderate grazing results in a contagious distribution of use. The effect results from selecting new herbage and avoiding the mature. Although that situation did not accurately describe the conditions in the communities of the study sites, the effect was the same. In this case, previous fall grazing or burning affected the distribution of forage utilization in spring by the uniformity with which litter was removed.

The barrier effect of stubble would also contribute to an explanation of declining animal gains with increased grazing pressure. The search effort becomes less profitable as the proportion of litter increases and the quality of green forage decreases. Hodgson *et al*. (1977) found significant correlation of foraging intake, by grazing calves, not only with the height of available forage but also with the proportion of green material in the forage stand. Forage height has also been related to forage intake by sheep (Allden 1961; Allden and Whittaker 1970). It appears that these relationships also hold for the extended height of forage above stubble and indicates that more careful consideration be given to management of residual litter.

Removing litter with fall burning or fall grazing (clipping) improved forage palatability and increased forage

utilization until the second year. First year results similar to those of this study were obtained by Barker and Erickson (1974) in North Dakota. Duvall and Whittaker (1964) found that burning bluestem (*Andropogon tener*) ranges reduced selectivity among grass species and resulted in uniform range use. Presumably selectivity among bluebunch wheatgrass plants would also be minimized by litter removal.

The burned treatment was preferred to the grazed treatment by both deer and cattle. By the second year the method of litter removal was important only to deer.

The decision to use fire or cattle to remove standing litter requires consideration of resources and desired effect. Palatability differences and, therefore, selectivity among plants should be minimal in the fall. However, geographic and biotic influences may need to be overcome with severe grazing pressure. Where this is not acceptable, in cases where animal weight losses are too severe or the animals are forced to select forage harmful to them, burning may be necessary.

Consideration of long term plant vigor may overwhelm those of short term plant quality. An example is the grazing practiced in the Kamloops area. Here the big sagebrush and lower Douglas fir zones are grazed by cattle in spring and fall. Deer, on the other hand, occupy the range in winter and early spring. Cattle grazing is normally managed to avoid damage by grazing after the plant has reached about 45% of its mature height and by avoiding over-use.

Consequently, cattle are not turned onto the range until late April and, more often, early May. Fall burning or severe fall defoliation by cattle in consecutive years repeatedly exposes the early spring growth to grazing by deer, who utilize the forage as it becomes available and may damage the plant. The result will be a decline of palatable forage as less palatable species become dominant, leading to a deterioration of range quality. To avoid this problem, burning must be done on manageable units (Wright 1974) or cattle grazing controlled to prevent extreme use in localized areas.

Bluebunch wheatgrass productivity may be expected to increase after the first year of fall burning. Avoiding repeated severe disturbance in the fall appears likely to increase both the forage yield and quality. Where the deer population is low or the area treated by fall burning or grazing is large, the susceptibility of individual plants to damage is also reduced. A sequence of fall burning, severe fall grazing and light fall grazing in consecutive years may optimize utilization, enhance the spring range for both deer and cattle and protect plant vigor.

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